STANDARDIZATION ROADMAP

FOR ELECTRIC VEHICLES

VERSION 1.0

Prepared by the

Electric Vehicles Standards Panel of the

American National Standards Institute

APRIL 2012

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Acknowledgments

The following professionals are acknowledged for their contributions and support to the development of this roadmap and for their participation in project meetings and teleconferences. The roadmap was developed based on their collective inputs, following a consensus process, and does not necessarily reflect the views of the organizations listed. The employment status and affiliations of participants with the organizations referenced are subject to change.

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Thanks and acknowledgment are given for the financial and in-kind support and participation of all the organizations that supplied experts to this initiative. Without the contributions of these individuals and their collective expertise, particularly those that chaired the various working groups and that participated actively, this final deliverable would not have been possible.

- Special acknowledgment and appreciation are given to Jim Matthews of Corning and Jim Pauley of Schneider Electric for serving as the EVSP co-chairs. Their guidance in helping to shape the initiative, lead its proceedings, and build consensus for the final deliverable were instrumental in reaching a successful outcome.

- Very special thanks go to Fred Wagner of Energetics who spent many hours editing the document and synthesizing the various inputs into a coherent report.

- Appreciation is given to the American National Standards Institute (ANSI) for the effective project management that kept this initiative on track and allowed for a successful delivery of the final publication in a timely manner, particularly from Jim McCabe and Rachel Howenstine.

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Executive Summary

Electric vehicles ("EVs," a/k/a electric drive vehicles) offer the potential to significantly reduce the United States' (U.S.) use of imported oil, create a multitude of well paying jobs through the establishment of a broad, domestic EV industry, and reduce on-road vehicular emissions. In order to achieve this potential, and broadly penetrate the consumer market, EVs must be undeniably safe, become more cost competitive, and otherwise satisfy user expectations and needs.

While there are many types of EVs, including those powered by fuel cells and other technologies, this roadmap's primary focus is on light duty, on-road plug-in electric vehicles (PEVs) that are recharged via a connection to the electrical grid, as well as the supporting charging infrastructure needed to power them. PEVs include full battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs). Some plug-in models are also extended range electric vehicles (EREVs) that function as a full BEV, plus have a feature to extend vehicle range beyond the battery (e.g., via a gasoline generator and other possibilities). Conventional hybrid EVs (HEVs) which are recharged by an internal combustion engine are yet another type of EV and, while not the focus of this roadmap, are noted where there are relevant safety and other considerations.

Given the current range limitations of plug-in EVs on battery power alone, a critical need is the establishment of a supporting charging infrastructure to enable vehicle recharging at home, at work, and in public locations. This infrastructure must be reliable and broadly interoperable regardless of the type of PEV or charging system utilized.

Equally important is the establishment of a comprehensive and robust support services sector that includes training of emergency first responders, vehicle technicians, electrical installers and inspectors, as well as education of authorities having jurisdiction, building owners, and consumers.

Never has there been a more auspicious time for EVs than the present. Nonetheless, while the times appear especially promising, EVs do face significant challenges to widespread adoption. In order for EVs to be broadly successful, the following challenges must be successfully addressed:

Safety: While inherently neither more nor less safe than conventional internal combustion engine vehicles, EVs do have unique safety complexities and risks which must be understood and accounted for as part of the vehicle life cycle.

Affordability. Cost is a critical issue which must be continually addressed in order for EVs to become widely accepted and broadly penetrate the consumer market.

Interoperability: The ability to recharge anywhere in a secure fashion will greatly enhance EV driver flexibility and user convenience.

Performance: The ability to extend the driving range of EVs on a single battery charge without the need for range extension is largely due to energy storage capabilities (batteries) and a function of technology development.

Environmental Impact: The demand from both regulators and consumers for “greener” vehicles (i.e., more fuel-efficient, less reliant on fossil fuels) must be met.

Standards, code provisions, and regulations, as well as conformance and training programs, cross over all these areas and are a critical enabler of the large-scale introduction of EVs and the permanent establishment of a broad, domestic EV and infrastructure industry and support services environment.

Roadmap Goals, Boundaries and Audience: In order to assess the standards and conformance programs needed to facilitate the safe, mass deployment of EVs and charging infrastructure in the United States, the American National Standards Institute (ANSI) convened the Electric Vehicles Standards Panel (ANSI EVSP or “the Panel”). The decision to form the Panel was made at a meeting of key stakeholders in March 2011 which ANSI convened in response to suggestions that the U.S. standardization community needed a more coordinated approach to keep pace with electric vehicle initiatives moving forward in other parts of the world. This effort draws upon participants from the automotive, utilities, and electrotechnical sectors as well as from standards developing organizations (SDOs) and government agencies.

The ANSI EVSP has produced this Standardization Roadmap for Electric Vehicles (“roadmap”) the goals of which are to:

1. Facilitate the development of a comprehensive, robust, and streamlined standards and conformance landscape; and

2. Maximize the coordination and harmonization of the standards and conformance environment domestically and with international partners.

Accordingly, the focus of this roadmap is to comprehensively identify, inventory, and assess existing standards, relevant codes and regulations, and related conformance and training programs, ascertain gaps and recommended solutions. This includes identification of prioritized timeframes and potential standards developing organizations (SDOs or “developers”) that may be able to lead the work.

It is important to emphasize that the focus of this roadmap is not merely to identify gaps and then to suggest development of new standards or conformance programs to fill them. Rather, it is also to identify opportunities where gaps potentially can be filled by revising or harmonizing existing standards and conformance programs.

Several high level boundaries have been established in the development of this roadmap. The focus is clearly upon on-road plug-in EVs (PEVs) consisting of battery electric vehicles (BEVs) and plug-in hybrid EVs (PHEVs), charging systems, and associated support services. Standards and conformance activities are emphasized that have direct applicability to the U.S. market for PEVs and charging infrastructure. Additionally, this roadmap has been developed with an eye toward international activities and harmonization, and a strong emphasis is placed upon establishing priorities for near-term standardization needs (0-2 years), while also assessing mid-term (2-5 years), and long-term (5+ years) requirements.

This roadmap is targeted toward a broad audience including standards development organizations (SDOs); U.S. federal, state, and municipal governments; and the automotive, electrotechnical, and utilities industries, among others.

Entities Operating in the EV Space: The U.S. standards system acknowledges that there are multiple paths to achieving globally relevant standards. Many SDOs and consortia operate on an international scale and what matters is that the standards are developed according to the principles of the World Trade Organization's Technical Barriers to Trade Agreement. Coordination and harmonization among international standardizing bodies is an aspirational goal that will help to foster innovation and grow global markets for EVs. Suffice it to say that the deployment of EVs in the United States will be shaped by the standards activities of a number of SDOs, both U.S.-based and non-U.S. based, as well as related conformance and training programs, other cross-sector initiatives, and codes and regulations.

Roadmap Structure: The broad electric vehicle and infrastructure system is very complex and dynamic, undergoing continual evolution and adaption, with many parties involved. In order to develop this roadmap, it was necessary to frame activities under three broad domains: vehicles, infrastructure, and support services. Within those three domains, seven broad topical areas of relevance to standards and conformance programs for electric vehicles were identified: energy storage systems, vehicle components, and vehicle user interface within the vehicle domain; charging systems, communications and installation within the infrastructure domain; and education and training within the support services domain.

While some distinct issues within the topical areas are solely applicable to one specific domain, in general they are highly interrelated and interdependent. In many, if not most cases, important issues related to standards and conformance programs cross over at least two of the domains simultaneously, if not all three. Understanding the interrelationships and interfaces between the domains, topical areas, and issues is essential.

Section 2 of the roadmap provides additional background regarding how this roadmap was developed and some of the key players that are shaping the standardization landscape.

Section 3 of the roadmap provides the context and explanation for why specific issues were considered important and subsequently assessed as part of this roadmap. Sections 3 and 4 parallel one another in structure to facilitate ease of use, cross comparisons, and consideration of issues across domains and topical areas.

Section 4 is the gap analysis of standards, codes, regulations, conformance programs, and harmonization efforts. This evaluation looks at existing and needed standards and conformance programs that are relevant to the rollout of electric vehicles and charging infrastructure in the United States. Where gaps are identified, recommendations for remediation are noted. Based on an assessment of the acuteness of risk, a priority for addressing the gap is noted, along with an indication of the potential developer(s) who could undertake the work.

Section 5 provides a summary of the gaps, recommendations and priorities by issue, including whether the identified gaps are grid-related.

Section 6 describes next steps and how this roadmap has been designed as a “living document’ which is flexible and adaptable, mirroring the EV environment.

Additionally, this roadmap is supplemented by the *ANSI EVSP Roadmap Standards Compendium*, a searchable spreadsheet which inventories standards that are directly or peripherally related to each issue, while also identifying related issues to which the standards potentially apply.

Summary of Gaps and Recommendations: Presently, this roadmap has identified a total of 36 gaps or partial gaps and corresponding recommendations across the three domains and seven topical areas. Twenty-two of these gaps / recommendations have been identified as near-term priorities, twelve as mid-term priorities, and two as long-term priorities.

Specifically, with regards to near-term safety and other priorities, the following gaps/partial gaps have been identified: delayed battery overheating events; safe storage of lithium-ion batteries; packaging and transport of waste batteries; audible warning systems; graphical symbols for EVs; wireless charging; battery swapping (both safety and interoperability); power quality; EVSE charging levels/modes; off-board charging station and portable EV cord set safety within North America; EV coupler safety within North America; EV coupler interoperability globally; conformance programs for EV coupler interoperability within the U.S. market; vehicle as supply / reverse power flow; use of alternative power sources; charging of roaming EVs between EVSPs; access control at charging stations; communication of standardized EV sub-metering data; vehicle emergency shutoff, including labeling of high voltage batteries, power cables, and disconnect devices; labeling of EVSE and load management disconnects; and, safe battery discharge / recharge in emergencies.

In this context, a gap refers to a significant issue – whether it be related to safety, performance, interoperability, etc. – that has been identified and that should be addressed in a standard, code, regulation, or conformance program but for which currently none is published or known to exist that adequately addresses the issue. Gaps can be filled through the creation of entirely new standards, code provisions, regulations, or conformance programs, or through revisions to existing ones. In some cases work may already be in progress to fill the gap.

A partial gap refers to a situation where a significant issue has been identified that is partially addressed by an existing standard, code, regulation, or conformance program. No gap means there is no significant issue that has been identified at this time or that is not already adequately covered by an existing standard, code, regulation, or conformance program.

Next Steps: While this version of the roadmap represents a specific snapshot in time, it maintains a distinctively outward looking, over the horizon posture that will facilitate discussions with domestic, regional and international partners regarding coordination and harmonization of standardization activities and adaption to technological and policy changes.

Moving forward, new elements of the roadmap will build on the foundation created here in anticipation of potential game changers resulting from revolutionary technology introductions, policy changes, or unforeseen incidents that could significantly impact the standards landscape for EVs and charging infrastructure.

Depending upon the realities of the standards environment, needs of stakeholders, and available resources, this roadmap will be periodically updated. It is envisioned that a first update will occur twelve to fifteen months after publication of this version one. During that time, it is anticipated that the ANSI EVSP will continue to assess the progress of standards and conformance programs, as well as gaps, focusing on developing issues that are new or that require further discussion.

Ultimately, the aim is to provide a living roadmap that will serve to help guide, coordinate, and enhance the standards landscape in support of the widespread introduction of EVs and charging infrastructure.

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1. Introduction

Electric vehicles ("EVs," a/k/a electric drive vehicles) offer the potential to significantly reduce the United States' (U.S.) use of imported oil, create a multitude of well paying jobs through the establishment of a broad, domestic EV industry, and reduce on-road vehicular emissions. In order to achieve this potential, and broadly penetrate the consumer market, EVs must be undeniably safe, become more cost competitive, and otherwise satisfy user expectations and needs.

While there are many types of EVs, including those powered by fuel cells and other technologies, this roadmap's primary focus is on light duty, on-road plug-in electric vehicles (PEVs) that are recharged via a connection to the electrical grid, as well as the supporting charging infrastructure needed to power them. PEVs include full battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs). Some plug-in models are also extended range electric vehicles (EREVs) that function as a full BEV, plus have a feature to extend vehicle range beyond the battery (e.g., via a gasoline generator and other possibilities). Conventional hybrid EVs (HEVs) which are recharged by an internal combustion engine are yet another type of EV and, while not the focus of this roadmap, are noted where there are relevant safety and other considerations.

Given the current range limitations of plug-in EVs on battery power alone, a critical need is the establishment of a supporting charging infrastructure to enable vehicle recharging at home, at work, and in public locations. This infrastructure must be reliable and broadly interoperable regardless of the type of EV or charging system utilized.

Equally important is the establishment of a comprehensive and robust support services sector that includes training of emergency first responders, vehicle technicians, electrical installers and inspectors, as well as education of authorities having jurisdiction, building owners, and consumers.

Standards, code provisions, and regulations, as well as conformance and training programs, cross over all these areas and are a critical enabler of the large-scale introduction of EVs and the permanent establishment of a broad, domestic EV and infrastructure industry and support services environment.

1.1 Situational Assessment for Electric Vehicles

Several factors are driving the keen interest in EVs. Certainly, U.S. government concerns over energy security and dependency on imported petroleum from increasingly unstable foreign markets is a primary driver. The potential of EVs to offer a solution to this problem, to contribute to the reduction of greenhouse gas emissions, and to promote economic growth and jobs creation in the new technologies, has spurred substantial government investment in electric vehicle research and infrastructure. In his 2011 State of the Union address, U.S. President Barack Obama announced the goal of putting one million electric vehicles on U.S. highways by 2015. There is also increasing demand for low-emission, fuel-efficient and affordable vehicles from consumers who want to demonstrate their commitment to the environment.

Never has there been a more auspicious time for EVs than the present. In recent years, there have been major advances in energy storage technologies (most especially lithium-ion based technologies) that have led to significant improvements in energy- and power density along with reduced costs. There have also been steady achievements with regards to hybrid power train developments, power electronics, and electric machines. Corporate average fuel economy (CAFÉ) requirements for 2016 and beyond provide an additional impetus behind EVs. And never before has there been such a broad interest and commitment by the automobile industry to the success of EVs.

Nonetheless, while the times appear especially promising, EVs do face significant challenges to widespread adoption. In order for EVs to be broadly successful, the following challenges must be successfully addressed: safety, affordability, interoperability, performance, and environmental impact. These also can be viewed as core values that will directly impact consumer acceptance of EVs. Standards, codes, regulations, and related conformance and training programs, are essential components that will aid in successfully addressing these concerns.

Safety: While inherently neither more nor less safe than conventional internal combustion engine vehicles, EVs do have unique safety complexities and risks which must be understood and accounted for as part of the vehicle life cycle. Given the high voltages and currents in EVs, battery and cable safety is especially important. This is true not only in accident situations for occupants and rescue personnel, but during charging, vehicle/battery repair, replacement, and recycling. Standards play an invaluable role in ensuring the safety of EV systems (and risks to technology manufacturers) especially if standards lead or at a minimum keep pace with and foreshadow technology evolution. Forward-leaning safety standards, codes, and regulations, complemented by conformance programs and training, are in fact essential to avoiding accidents and public safety risks that potentially could adversely affect the widespread viability of EVs.

Affordability: Cost is a critical issue which must be continually addressed in order for EVs to become widely accepted and broadly penetrate the consumer market. EVs are more expensive than conventional vehicles, largely driven by battery capital and replacement costs which are related to economies of scale, manufacturing technology, and raw materials. Likewise, the cost of infrastructure technology and installation needs to be reduced to bring the overall EV system life cycle cost in line with that of conventional vehicles.

While standards, codes, and regulations do not directly impact the cost of EV systems, they do so indirectly. For example, comprehensive, clear, and forwardly insightful standards and codes reduce risk and uncertainty for technology developers and investors, serving as an insurance policy of sorts. A well designed and fully developed standard and code environment encourages competition through facilitation of new market entrants and increased private sector investment.

Interoperability: The ability to recharge anywhere in a secure fashion will greatly enhance EV driver flexibility and user convenience. Well established interoperability standards and communications systems which facilitate the ability to remotely locate, price compare, and reserve charging sites along travel routes will be invaluable, especially in the early years of EV deployment given the relative scarcity of charging infrastructure. Billing under different charging scenarios must be seamless and efficient.

It will be important for standards to be designed to facilitate upgrade paths and flexible compatibility with quickly evolving communications and smart grid technologies. A bit further out possibly, but also important, are standards to facilitate vehicle energy to home and grid applications. Significantly greater interoperability will lead to manufacturing efficiencies for both the vehicle and built infrastructure leading to greater affordability and reduced financial risk.

Performance: The ability to extend the driving range of PEVs on a single battery charge without the need for range extension is largely due to energy storage capabilities (batteries) and a function of technology development. As standards, codes, and regulations help to reduce overall risk, it is likely that more technology firms will enter the market and investment will increase, thereby leading to a quickened pace of technology advancement. Standards for fast charging will help to define this market, accelerate development of more cost effective fast charging systems, enhance user convenience, and extend EV driving range. These factors will enhance business and consumer confidence in, and electric driving performance of, PEVs, making them increasingly attractive as a practical and reliable alternative to conventional vehicles.

Environmental Impact: The demand from both regulators and consumers for "greener" vehicles (i.e., more fuel-efficient, less reliant on fossil fuels) must be met. This will continue to drive technological developments and standardization efforts within the auto industry. This includes batteries with enhanced storage capacity as well as investigation of renewables as alternative power sources. The ability to safely and efficiently recharge EVs in residential, commercial and public settings without adverse grid impacts is essential, and also the subject of standardization activity and technological advancements.

1.2 Roadmap Goals for EVs and Charging Infrastructure

In order to assess the standards and conformance programs needed to facilitate the safe, mass deployment of EVs and charging infrastructure in the United States, the American National Standards Institute (ANSI)[1] convened the Electric Vehicles Standards Panel (ANSI EVSP or "the Panel"). The ANSI

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[1] ANSI is a non-profit organization that coordinates the U.S. private sector standards and conformance system – a system that relies upon close collaboration and partnership between the public and private sectors. ANSI represents thousands of member companies, organizations, and individuals who rely upon standards and conformance to increase efficiency, create market acceptance, improve competitiveness, and foster international commerce. For more than ninety years, ANSI and its members have worked to demonstrate the strength of private sector-led and public sector-supported, market-driven, standards-based solutions that are characterized by consensus, openness, and balance. ANSI is the U.S. member of the International Organization for Standardization (ISO) and, via the U.S. National Committee, the International Electrotechnical Commission (IEC).

EVSP has produced this Standardization Roadmap for Electric Vehicles ("roadmap") the goals of which are to:

1. Facilitate the development of a comprehensive, robust, and streamlined standards and conformance landscape; and

2. Maximize the coordination and harmonization of the standards and conformance environment domestically and with international partners.

Accordingly, the focus of this roadmap is to comprehensively identify, inventory, and assess existing standards, relevant codes and regulations, and related conformance and training programs, ascertain gaps and recommend solutions. This includes identification of prioritized timeframes and potential standards developing organizations (SDOs or "developers") that may be able to lead the work. This roadmap also aspires to discuss coordination of SDOs and oversight bodies (domestic and international), as well as provide a framework to monitor the evolving technical and policy landscape for EVs and infrastructure with regards to standards and conformance programs.

It is important to emphasize that the focus of this roadmap is not merely to identify gaps and then to suggest development of new standards or conformance programs to fill them. Rather, it is also to identify opportunities where gaps potentially can be filled by revising or harmonizing existing standards and conformance programs.

1.3 Roadmap Boundaries

In order to manage scope, emphasize priorities, and adhere to a compressed timetable, several high level boundaries have been established in the development of this roadmap:

- The emphasis is on standards and conformance programs that are specific to on-road plug-in EVs (PEVs) consisting of battery electric vehicles (BEVs) and plug-in hybrid EVs (PHEVs), charging infrastructure, and associated support services, as opposed to other types of EVs or more general road vehicle and electrical infrastructure standardization activity.

- Standards and conformance programs that address the key challenges and core consumer values of safety, affordability, interoperability, performance, and environmental impact are targeted.

- Standards and conformance activities that have direct applicability to the U.S. market for PEVs and charging infrastructure are the primary focus.

- This roadmap has been developed with an eye toward international activities and harmonization, especially with regards to Canada and the European Union (EU). Harmonization refers to efforts to align or make equivalent the requirements in standards and conformance programs.

- As a result of the acute need for standards and conformance programs to pace the rapidly evolving EV environment, a strong emphasis is placed upon establishing priorities for near-term standardization needs (0-2 years), while also assessing mid-term (2-5 years) and long-term (5+ years) requirements.

1.4 Roadmap Audience

This roadmap is targeted toward a broad audience including standards development organizations (SDOs); U.S. federal, state, and municipal governments; and the automotive, electrotechnical, and utilities industries, among others.

This roadmap may assist SDOs in identifying priority areas, establishing boundaries, and identifying opportunities for collaboration, consolidation, and harmonization. In addition, as specific gaps are identified for the overall EV standards landscape, it will be easier for SDOs to prioritize their activities over the near-term, mid-term, and long-term timeframes.

This roadmap will assist federal and state government entities in establishing a coherent and coordinated U.S. EV policy, and participating in or tracking the progress of associated technical activities. It will also assist harmonization efforts with regional and international entities on needed standards and conformance programs.

This roadmap will serve municipal governments and other like entities in understanding the issues and complexities surrounding EVs, infrastructure, and supporting services, and where to find resolution when looking to establish EV deployment strategies in local communities.

This roadmap will help industry to target standards participation efforts, and aid in the development of EV technologies and related conformance programs. It will also enable industry to identify commercial opportunities, to gain insights to support business strategies and technology sequencing, and to reduce safety and economic risks.

1.5 Roadmap Structure

The broad electric vehicle and infrastructure system is very complex and dynamic, undergoing continual evolution and adaptation, with many parties involved. In order to develop this roadmap, it was necessary to frame activities under three broad domains: Vehicles, Infrastructure, and Support Services. Within those three domains, seven broad topical areas of relevance to standards and conformance programs for electric vehicles were identified: Energy Storage Systems, Vehicle Components, and Vehicle User Interface within the Vehicle Domain; Charging Systems, Communications and Installation within the Infrastructure Domain; and Education and Training within the Support Services Domain. Figure 1 illustrates this.

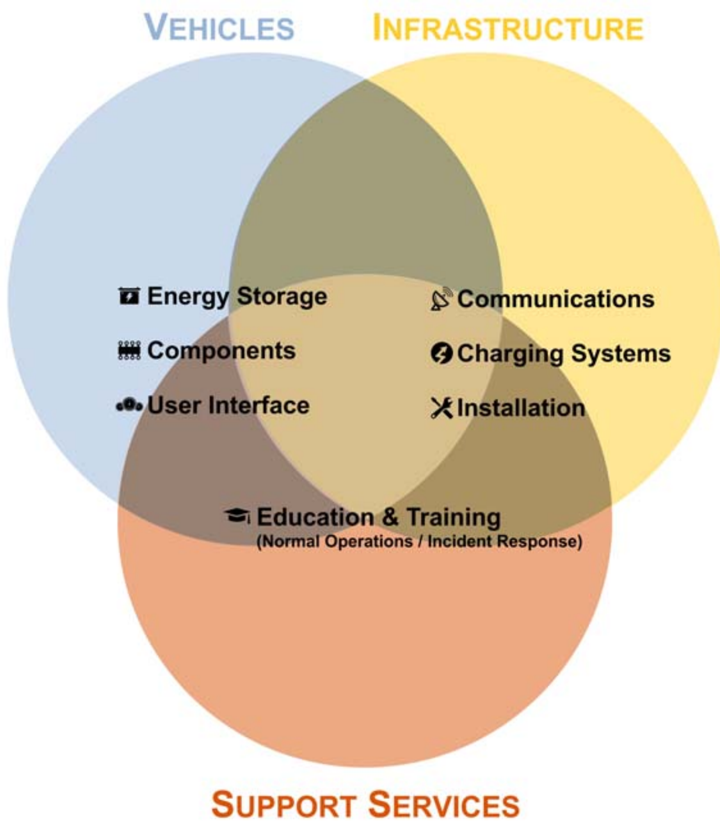

Figure 1: Domains and Topical Areas for the Standardization Roadmap for Electric Vehicles

While some distinct issues within the topical areas are solely applicable to one specific domain, in general they are highly interrelated and interdependent. In many, if not most cases, important issues related to standards and conformance programs cross over at least two of the domains simultaneously, if not all three. Understanding the interrelationships and interfaces between the domains, topical areas, and issues is essential.

Section 2 of the roadmap provides additional background regarding how this roadmap was developed and some of the key players that are shaping the standardization landscape.

Section 3 of the roadmap provides the context and explanation for why specific issues were considered important and subsequently assessed as part of this roadmap. Sections 3 and 4 parallel one another in structure to facilitate ease of use, cross comparisons, and consideration of issues across domains and topical areas.

Section 4 is the gap analysis of standards, codes, regulations, conformance programs, and harmonization efforts. This evaluation looks at existing and needed standards and conformance programs that are relevant to the rollout of electric vehicles and charging infrastructure in the United States. Where gaps are identified, recommendations for remediation are noted. Based on an assessment of the acuteness of risk, a priority for addressing the gap is noted, along with an indication of a potential developer(s) who could undertake the work.

Section 5 provides a summary of the gaps, recommendations and priorities by issue, including whether the identified gaps are grid-related.

Section 6 describes next steps and how this roadmap has been designed as a "living document" which is flexible and adaptable, mirroring the EV environment.

This roadmap is supplemented by the ***ANSI EVSP Roadmap Standards Compendium,*** a searchable spreadsheet which inventories standards that are directly or peripherally related to each issue, while also identifying related issues to which the standards potentially apply.[2]

[2] The ***ANSI EVSP Roadmap Standards Compendium*** can be found at http://publicaa.ansi.org/sites/apdl/evsp/ANSI_EVSP_Roadmap_Standards_Compendium.xls. Note: As this is a spreadsheet, your browser may give you a security warning in order to open it.

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2. *Background*

2.1 How the Roadmap was Developed

The ANSI EVSP was convened to conduct the standardization needs assessment for EVs, with a view to assuring that the technologies and infrastructure are effective, safe, and ready to accommodate a major shift in our national automotive landscape. Drawing participants from the automotive, utilities, and electrotechnical sectors as well as from standards developing organizations (SDOs) and government agencies, the Panel is a continuation of a series of standards coordinating activities where ANSI has brought together stakeholders from the private and public sectors to work in partnership to address national and global priorities. As ANSI itself does not develop standards, the Panel is strictly a coordinating body intended to inventory and assess but not duplicate current work. The actual development of standards for EVs and related infrastructure is carried about by various SDOs.

The decision to form the Panel was made at a meeting of key stakeholders in March 2011 which ANSI convened in response to suggestions that the U.S. standardization community needed a more coordinated approach to keep pace with electric vehicle initiatives moving forward in other parts of the world. The need for improved coordination was reinforced at an April 5-6, 2011 ANSI Workshop on *Standards and Codes for Electric Drive Vehicles,* convened on behalf of the U.S. Department of Energy and the Idaho National Laboratory (see workshop report and proceedings at www.ansi.org/edv).

Formally launched in May 2011, the ANSI EVSP set out to produce a strategic roadmap of the standards and conformance programs needed to facilitate the safe, mass deployment of electric vehicles and charging infrastructure in the United States. From the outset, the Panel was also envisioned as a resource to better enable the United States to speak with a coherent and coordinated voice in policy and technical discussions with regional and international audiences on needed standards and conformance programs related to electric vehicles.

Seven working groups were organized to conduct the standardization needs assessment. The working groups mirrored the topical areas within this roadmap: Energy Storage Systems, Vehicle Components and Vehicle User Interface within the Vehicle Domain; Charging Systems, Communications and Installation within the Infrastructure Domain; and Education and Training within the Support Services Domain.

Following an initial plenary meeting held June 20-21, 2011, the working groups met virtually over the course of several months to identify existing and needed standards and conformance programs, as well as gaps and harmonization issues. Individual working group members subsequently drafted sections of the roadmap based on the discussions. These were reviewed by the working groups individually and later collectively at the Panel's second plenary meeting held November 17-18, 2011 and in subsequent conference calls. The roadmap development process was characterized by open participation and consensus-based decision-making.

For purposes of defining the scope of this roadmap version one, the Panel agreed to apply the definition of electric vehicle found in the 2011 version of NFPA 70®, the National Electrical Code® (NEC®), given below, with the primary focus being on-road vehicles containing a battery that is recharged via the electrical grid, and related infrastructure.

> *Electric Vehicle*. An automotive-type vehicle for on-road use, such as passenger automobiles, buses, trucks, vans, neighborhood electric vehicles, electric motorcycles, and the like, primarily powered by an electric motor that draws current from a rechargeable storage battery, fuel cell, photovoltaic array, or other source of electric current. Plug-in hybrid electric vehicles (PHEV) are considered electric vehicles. For the purpose of this article, off-road, self-propelled electric vehicles, such as industrial trucks, hoists, lifts, transports, golf carts, airline ground support equipment, tractors, boats, and the like, are not included. (NFPA 70®, 2011 version)

In addition to what is not included in the NFPA 70® definition, the Panel further agreed to not include aircraft, or vehicles on fixed guideways (e.g. rails, monorails) such as trains or trolleys. While not relevant to the infrastructure discussion applicable to PEVs and PHEVs, the panel agreed to consider in part hybrid electric vehicles (HEVs) that are recharged by internal combustion engines to the extent that they pose safety concerns, e.g., for emergency responders.

2.2 Entities Operating in the EV Standards Space

The deployment of electric vehicles is both a national issue and a global challenge. While in some cases national requirements will define the specific approach to an issue, in many areas international norms will provide the necessary direction. The U.S. standards system acknowledges that there are multiple paths to achieving globally relevant standards. Many SDOs and consortia operate on an international scale and what matters is that the standards are developed according to the principles of the World Trade Organization's Technical Barriers to Trade Agreement, which are also consistent with ANSI's *Essential Requirements: Due process requirements for American National Standards*. The process must be consensus-based, open, with balanced participation – and include all the other elements that are the hallmarks of the U.S. standards system. Coordination and harmonization among international standardizing bodies is an aspirational goal that will help to foster innovation and grow global markets for EVs.

Suffice it to say that the deployment of EVs in the United States will be shaped by the standards activities of a number of SDOs, both U.S.-based and non-U.S. based, as well as related conformance and training programs, other cross-sector initiatives, and codes and regulations. Listed below are some of the principal SDOs, government agencies, organizations, and initiatives that are influencing the roll-out of EVs in the United States.

2.2.1 U.S.-based SDOs

SAE International: SAE standards development activity covers a wide range of EV issues. These include the alternating current (AC) charge coupler standard SAE J1772™ which is incorporated into IEC 62196-2 and is currently under revision to incorporate direct current (DC) charging. SAE also has published a power quality specification SAE J2894. SAE is also working on documents related to vehicle-to-grid and vehicle-to-off-board charger communications (the J2836™ and J2847 series of documents and J2931 and J2953), and is working closely to harmonize these standards with its IEC and ISO counterparts. SAE also is working on J2954, a wireless charging standard and, again, is working with ISO on harmonization. Other EV issues addressed by SAE standards include battery design, packaging, labeling, safety, transport, handling, recycling, and secondary uses; energy transfer systems, terminology, etc. SAE International administers the U.S. mirror committee (a/k/a U.S. technical advisory group or TAG) for ISO/TC 22/SC 21 on electrically propelled road vehicles.

Underwriters Laboratories Inc.: UL standards for EVs address safety-related concerns for batteries (UL 2271 and UL 2580); electric vehicle supply equipment (EVSE) (UL 2594); personnel protection systems (UL 2231-1 and UL 2231-2); EV charging system equipment (UL 2202); plugs, receptacles and connectors (UL 2251); on-board cables (UL 2733); electric utility (smart) meters (UL 2735), etc. UL is currently developing requirements for electric vehicle power supplies (UL 2747) and electric vehicle wireless charging equipment (UL 2750). UL administers the U.S. mirror committee (U.S. TAG) for IEC/TC 69 on electric road vehicles and electric industrial trucks. UL also administers the U.S. mirror committee (e-TAG) for IEC SMB SG6, Electrotechnology for Mobility.

National Fire Protection Association: NFPA's standards development activities include NFPA 70®, the National Electrical Code® (NEC®), which is adopted throughout the U.S. and is adopted as part of, or incorporated into, all U.S. model building codes and residential construction codes. It provides a uniform standard for residential, commercial, and industrial electrical installations for EV charging equipment in North America. NFPA is also very active in conducting EV safety training for emergency first responders under a grant from the U.S. Department of Energy and in partnership with several vehicle manufacturers. NFPA and SAE co-hosted two U.S. national EV safety standards summits, in 2010 and 2011 (see reports at http://www.evsafetytraining.org/Resources/Research.aspx).

IEEE: IEEE publishes the IEEE 1547 series of Standards for Interconnecting Distributed Resources with Electric Power Systems and the IEEE P2030.1 Draft Guide for Electric-Sourced Transportation Infrastructure. IEEE also publishes and develops Power Line Communication (PLC) standards: 1901-2010 Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for High Rate Wireless Personal Area Networks (WPANs), and IEEE P1901.2, Draft Standard for Low Frequency (less than 500kHz) Narrow Band Power Line Communications for Smart Grid Applications.

International Code Council: ICC publishes the International Building Code® (IBC®) and International Residential Code® for One- and Two-Family Dwellings (IRC®), the model codes used as the commercial and residential codes in all 50 states, and the International Fire Code (IFC®) used by 43 states as the fire code. As such, any new or revised standard or codes with specific provisions relating to EVs or EVSE, such as the National Electrical Code®, will need to be integrated into or referenced by the I-Codes®. Training will need to be provided to code officials and fire inspectors if such requirements are to gain wide acceptance and use at the state and local levels of government, where building requirements are adopted and enforced.

National Electrical Contractors Association: NECA has developed NECA 413 for the electrical contracting industry. This standard describes the procedures for installing and maintaining EVSE for AC Levels 1 and 2 and DC fast charging.

National Electrical Manufacturers Association: NEMA has established an EVSE systems section that is working to promote the EVSE infrastructure around the world. NEMA has been working with UL and the Canadian Standards Association (CSA) to harmonize EVSE requirements in North America.

Alliance for Telecommunications Industry Solutions: ATIS is exploring two use cases: charging an EV from someone else's private home and charging from a public charging portal, with respect to both connected vehicle and smart grid standardization. ATIS will investigate the role that telecom operators can provide in these use cases with respect to cellular and fixed wide area communications, service layer capabilities such as security, quality of service (QoS), priority, device provisioning, management, and charging. This investigation will include the identification of any gaps in information and communications technology (ICT) standardization needed to satisfy these use cases.

2.2.2 Non U.S.-based SDOs

International Electrotechnical Commission: There are a number of IEC technical committees (TC) and subcommittees (SC) dealing with EVs including IEC/TC 69, which has produced the IEC 61851 standards on Electric vehicle conductive charging, and IEC/23H, which is responsible for IEC 62196 parts 1 and 2 on Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles. On January 19, 2011, IEC and e8, a global organization of the world's leading electricity companies (now known as the Global Sustainable Electricity Partnership), brought together major stakeholders for a roundtable to determine priorities for the development of EV-related standards that will enable global interoperability and connectivity. See http://www.iec.ch/newslog/2011/nr0411.htm. At its October 24, 2011 meeting, the IEC Standardization Management Board (SMB) formed Strategic Group 6, Electrotechnology For Mobility, to provide the SMB and IEC TCs with a strategic vision and assistance to address standardization needs on systems and products to be used for interfacing plug-in electric vehicles with electricity supply infrastructure.

International Organization for Standardization: ISO has entered into a memorandum of understanding with IEC to improve cooperation on standards for electric vehicles and automotive electronics. The agreement creates a framework of cooperation between ISO/TC 22, road vehicles, with a number of IEC TCs/SCs. The agreement covers on-board equipment and performance of road vehicles, and the interface between externally chargeable vehicles and electricity supply infrastructure. Annex A of this agreement lists ISO and IEC (TCs and SCs) standardization activities in the field of electrotechnology for road vehicles. Annex B of this agreement lists current modes of cooperation. See http://www.iso.org/iso/pressrelease.htm?refid=Ref1402.

CEN CENELEC: The European Standards Organizations (ESOs) CEN, the European Committee for Standardization, and CENELEC, the European Committee for Electrotechnical Standardization, formed a Focus Group that produced in June 2011 a Report on European Electro Mobility in response to the European Commission/European Free Trade Association (EFTA) mandate M/468 concerning the charging of electric vehicles.[3] A second edition of the Report was published in October 2011 with minor amendments, following Technical Board discussion. See www.cen.eu/go/eMobility. The mandate was focused on ensuring electric vehicle charging interoperability and connectivity in all EU member states, as well as addressing smart charging, and safety and electromagnetic compatibility of EV chargers. The October 11, 2011 ANSI-ESO Joint President's Group (JPG) Meeting included a discussion of European Union (EU)-U.S. standards cooperation on electric vehicles. A European level Coordination Group has been established to ensure that the recommendations contained in the report are implemented. Cooperation between the Coordination Group and the ANSI EVSP is being pursued including the convening of a Transatlantic E-mobility Standardization Roundtable in 2012.

2.2.3 U.S. Federal Government Agencies

U.S. Department of Energy: DOE is supporting the development of this standardization roadmap and the growth of the EV market on a number of fronts. In February 2011, DOE produced a report *One Million Electric Vehicles by 2015* providing an analysis of advances in electric vehicle deployment and progress in meeting President Obama's goal of putting one million electric vehicles on the road by 2015. The analysis shows that while the goal is ambitious, it is also achievable based on steps already taken as part of the Recovery Act and additional policy initiatives proposed by President Obama -- including improvements to existing consumer tax credits, programs to help cities prepare for the growing demand for electric vehicles, and strong support for research and development to continue reducing the cost of electric vehicles. See

http://energy.gov/downloads/microsoft-word-1-million-electric-vehicle-report-final.

DOE's Transportation Electrification Demonstration Projects are a nationwide effort to mine data to assist in the widespread deployment of EV charging stations. The project includes the deployment of 13,000 electric vehicles, the installation of more than 20,000 charging stations, and funding of programs for first responders on how to handle accidents involving EVs. Data collected in the project will include vehicle and charger performance, charging patterns and public charger use, the impact of various rate structures on charging habits, and the impact of vehicle charging on the electric grid.

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[3] The Intelligent Transport community within the European Telecommunications Standards Institute (ETSI) is discussing the European mandate with the Car-To-Car Consortium (C2C CC) in order to investigate the work that may be required to answer the communications aspects in reply to the mandate M/468.

DOE participates, alongside U.S. automakers, national laboratories and utilities, in the U.S. DRIVE Grid Interaction Tech Team which is working to identify and support the reduction of barriers to large scale introduction of grid connected vehicles. DOE also has programs for advanced vehicle testing and has issued a number of grant-funded projects to promote education of the workforce in relation to EVs.

U.S. General Services Administration: To further the president's goals of reducing the country's dependence on oil imports by one-third by 2025 and putting 1 million advanced technology vehicles on the road, GSA launched the government's first Electric Vehicle Pilot Program. The pilot is a targeted investment to incorporate electric vehicles and charging infrastructure into the federal government's vehicle and building portfolios as a first step to growing the number of electric vehicles in the federal fleet over time.

National Highway Traffic Safety Administration: An agency of the U.S. Department of Transportation, NHTSA maintains the U.S. Federal Motor Vehicle Safety Standards (FMVSS) and Regulations to which manufacturers of motor vehicle and equipment items must conform and certify compliance. In addition to having to comply with crashworthiness, crash avoidance and other standards also applicable to conventional vehicles, EVs sold in the U.S. must additionally comply with FMVSS 305 which addresses electrolyte spillage, intrusion of propulsion battery system components into the occupant compartment, and electrical shock. In 2012, NHTSA is expected to propose a new safety standard that will require EVs to be equipped with audible alerts so that blind and other pedestrians can detect a nearby EV when being operated at low speed. Research projects are also underway on crash avoidance and performance.

NHTSA is also the U.S. representative to the World Forum for Harmonization of Vehicle Regulations (WP.29). As the name implies, WP.29 provides a forum for the development of Global Technical Regulations (GTRs) for vehicles which can be adopted by governments around the world. The Secretariat is provided by the UNECE (United Nations Economic Commission for Europe).

2.2.4 Other Cross-Sector Initiatives

Smart Grid Interoperability Panel: The SGIP, formed in November 2009, engages stakeholders from the entire smart grid community in a participatory public process to identify applicable standards, gaps in currently available standards, and priorities for new standardization activities for the evolving smart grid. SGIP supports the National Institute of Standards and Technology (NIST) in fulfilling its responsibilities under the 2007 Energy Independence and Security Act.

Within the SGIP there are working groups of experts within a particular domain. As electric vehicle to grid interaction has been determined to be a critical issue, a Vehicle to Grid Domain Expert Working Group (V2G DEWG) was created in 2009 to analyze vehicle to grid interoperability.

The V2G DEWG provides a strategic view of interoperability needs and standards gaps related to the interaction and communications between the electric vehicle, the charging system, the power grid, and the user. The V2G DEWG has six subgroups: Road-mapping, Security, Privacy, EV as Storage, Roaming, and Regulatory, with an additional subgroup for sub-meter issues being formed. When the V2G DEWG identifies critical roadblocks or gaps in any of these areas, an SGIP Priority Action Plan (PAP) is formed.

These tactical PAPs facilitate and coordinate stakeholders and SDOs in overcoming standards related challenges. The first SGIP V2G-related PAP was PAP 11 focused on common information for EVs. This PAP was closed out in 2011 with the successful approval of the SGIP of three SAE standards: J2836™, J2847, and J1772™. A new PAP is in the process of being created to address fast charging issues including the need for standardized fast charge connectors and communications.

The SGIP can redirect issues identified by the V2G DEWG that are out of scope of the SGIP to the ANSI EVSP and share with the ANSI EVSP information on electric vehicle infrastructure standardization needs and gaps. The ANSI EVSP in turn can identify standardization needs and gaps that can inform the work of the V2G DEWG and facilitate the development of SGIP PAPs.

TransAtlantic Business Dialogue: The TABD supported the development of an EV agenda for the TransAtlantic Economic Council (TEC). In March 2011, TABD members Audi and Ford drafted an E-Mobility Work Plan for the TEC. ACEA (the European Automobile Manufacturers Association), the Alliance of Automobile Manufacturers and others provided input and the plan was endorsed by the TABD. On May 12, 2011 the plan was submitted to the TEC Co-Chairs within the White House and the European Commission. It was further refined in preparation for the November 2011 TEC meeting. In addition, the October 12, 2011 ANSI – ESO Conference on Transatlantic Standardization Partnerships included a session on E-Mobility/Electric Vehicles, organized in partnership with the TABD. The event brought together high-level U.S. and European government officials, corporate executives from the automobile industry, and experts from key standards developing bodies, to share perspectives on efforts underway to develop a common approach and schedule for joint electric vehicle standardization activities. At that event, EU Trade Commissioner Karel De Gucht called on participants to form a transatlantic e-mobility standardization roundtable to facilitate transatlantic cooperation on standardization.

National Electric Transportation Infrastructure Working Council: Sponsored by the Electric Power Research Institute (EPRI), the IWC is a group of individuals whose organizations have a vested interest in the emergence and growth of the EV and PHEV industries, as well as the electrification of truck stops, ports, and other transportation and logistic systems. IWC members include representatives from electric utilities, vehicle manufacturing industries, component manufacturers, government agencies, related industry associations, and standards organizations. IWC committees meet several times a year.

Electric Drive Transportation Association: EDTA is an industry association dedicated to advancing electric drive as a foundation for sustainable transportation. Since 1989, EDTA has led efforts to provide federal support for electric drive research, demonstration and manufacturing, and to provide significant incentives for the purchase of electric vehicles and chargers, and the promotion of EV infrastructure development in the U.S.

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The above is not an exhaustive list. With new activities taking place everyday, the ANSI EVSP has endeavored to track significant activities by various entities which are helping to shape the standards and conformance landscape for EVs both in the United States and internationally. A list of selected standardization and related coordination activities can be found on the Panel's website at www.ansi.org/evsp.

3. Identification of Issues

Section 3 introduces the issues that are subsequently assessed in the standardization gap analysis in section 4 of the roadmap. The interrelationship of issues, combined with the dynamic nature of electric vehicle and infrastructure technology and the evolving policy environment, poses some unique challenges to the development of a comprehensive, coordinated, and streamlined Standardization Roadmap for Electric Vehicles.

3.1 Vehicle Domain

For purposes of this roadmap, the Vehicle Domain generally encompasses the technologies, equipment, components, and issues that fall within the strict confines of the electric vehicle itself up to and including the vehicle inlet portion of the charge coupler. The following sections under the Vehicle Domain, 3.1.1 Energy Storage Systems, 3.1.2 Vehicle Components, and 3.1.3 Vehicle User Interface, discuss the relevant issues that fall under these topical areas and why they are important with regards to standardization, harmonization, and conformance activities. The interrelationship of issues within the Vehicle Domain is illustrated in Figure 2.

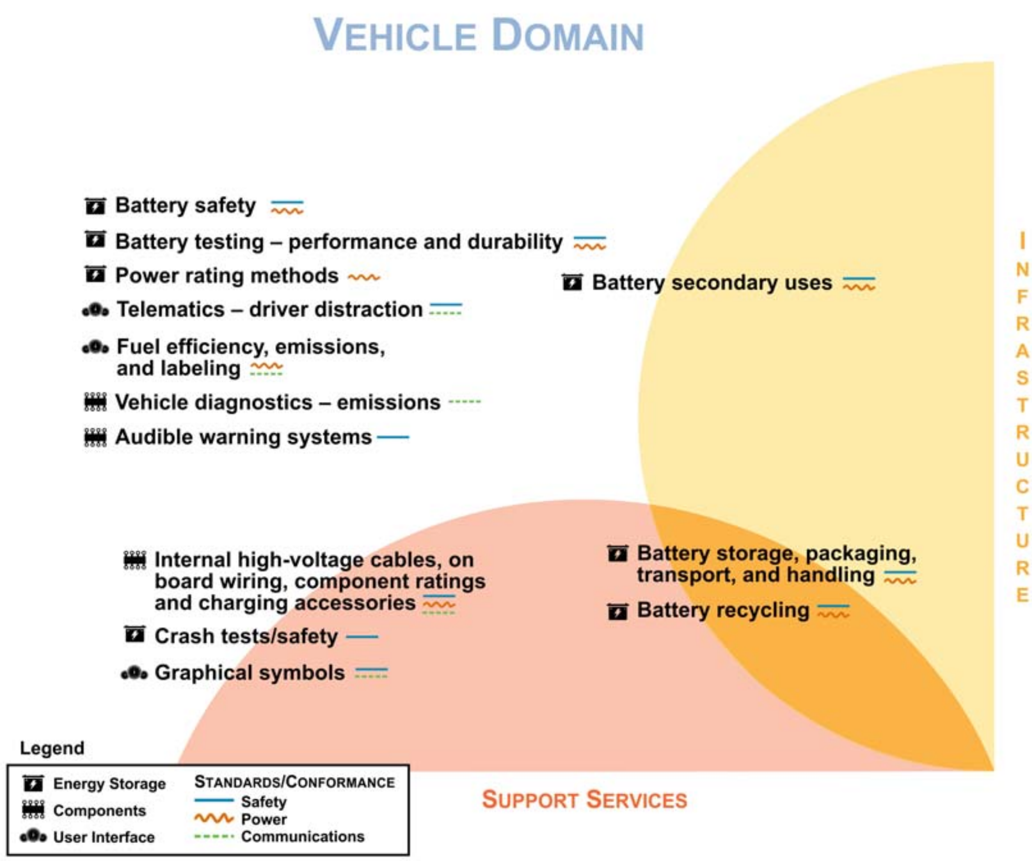

Figure 2: Interrelationship of Issues within the Vehicle Domain

Terminology

On a general note from the outset, it is important for consistent vocabulary to be used for electric vehicle terminology to assist in the development of standards for electric vehicles, as this will provide a consistent understanding of important concepts.

3.1.1 Energy Storage Systems

The Energy Storage Systems topical area primarily relates to battery energy storage and related subsystems but may also include other energy storage systems, including fuel cells and mechanical energy storage. The most common type of batteries being developed for electric transportation are lithium-ion-based. Topics addressed include battery safety; battery testing – performance and durability; battery storage, packaging, transport and handling; battery recycling; battery secondary uses; and, crash tests/safety.

3.1.1.1 Power Rating Methods

Power rating methods are important for hybrid electric vehicles and battery electric vehicles in order to define test methods and conditions for rating the performance of electric propulsion motors as used in these vehicles, as well as thermal and battery capabilities and limitations.

3.1.1.2 Battery Safety

For electric vehicles to meet their full potential in the market place, the public needs to see them as at least as safe as the vehicles they replace. Effective safety standards ensure that electric vehicles are safe for occupants, other motorists, children, service technicians, and first responders. Safety standards mainly consist of tests, intended to duplicate real-world events. Compliance to an EV battery safety standard demonstrates that the EV battery meets a minimum safety criteria established by that standard. Safety standards not only protect the public – they also help protect manufacturers from legal challenges that may arise. Vehicle manufacturers desire global harmonization of safety standards that are effective without imposing unnecessary costs or limits to innovation.

3.1.1.3 Battery Testing – Performance and Durability

Battery testing incorporates both the performance and durability of cells, modules and full battery packs, as well as the battery management system. Test standards related to battery abuse, product safety, or transportation/handling are addressed in other sections of the Energy Storage Systems topical area of this roadmap.

3.1.1.4 Battery Storage, Packaging, Transport and Handling

Battery Storage

EV Batteries (including HEV and PHEV) will require storage throughout many stages of their life cycle, namely – prior to market distribution by manufacturers, in import/export locations, logistic centers, battery swapping (switching) stations including warehousing, repair workshops, as well as garages following accidents, recovered vehicle storage lots, auto salvage yards, and at end-of-life in recycling facilities. Traceability and life cycle management are important. Differentiation between new and waste batteries (damaged, aged, sent for repair, end-of-life) batteries is also significant. The risk of a stored battery must be evaluated based on several parameters, including, but not limited to, state of charge (SOC), mechanical wholeness, and age of the battery.

Battery storage issues of concern include: high temperature controls (particularly significant for battery swapping stations during charging), humidity control including adequate air circulation and ventilation to prevent explosive gas atmospheres (especially significant for damaged batteries), hydrogen/oxygen detection, storage of damaged batteries away from other batteries and combustible materials, and fire prevention and extinguishing systems.

Battery Packaging, Transport and Handling

Three significant use cases exist with respect to battery packaging, transport and handling:

- Battery packaging and design for the transportation between the battery manufacturer and the vehicle manufacturer;
- Battery packaging and design for battery transportation to workshops or battery swapping stations; and
- Battery packaging for the transportation of damaged batteries.

Transport by ground, air and sea of EV batteries (including those for HEVs and PHEVs) presents a unique risk to their supply chain handlers, as their weight and volume are significantly higher than common consumer batteries. This risk grows further when handling aged and damaged batteries. For example, there may be needed packaging for a damaged or deformed battery to account for possible leakage of materials.

3.1.1.5 Battery Recycling

Battery end-of-life, either through damage beyond repair or full exhaustion following use, requires special consideration from the environmental, geo-political and economical points of view. As electric vehicle battery manufacturing relies on natural minerals mining, and improper disposal may potentially result in soil, groundwater and air pollution, the technology for efficient battery recycling is fast growing. Lead-acid batteries, by comparison, have reached nearly 100% recycling rates worldwide.

Lithium-based batteries are expected to be the main chemistry for the foreseeable future, and are projected to take up nearly 40% of the consumable world lithium by 2020. Positive value for recycling these batteries is likely to be through the nickel and cobalt components, as the lithium itself is a small fraction of the battery, and rather inexpensive. Additional challenges stem from the fact that many battery chemistries exist with different lithium combinations and pack geometries, which makes it hard to develop industrial-scale precise recycling processes with high recovery rates and efficiency. Additionally, not all battery chemistries may have a value (e.g. iron phosphate).

3.1.1.6 Battery Secondary Uses

A secondary life for both fixed and removable electric vehicle batteries may include re-use for other vehicular applications and grid and low-power applications. This can include fulfilling different grid functionalities including storing energy and helping to stabilize grids utilizing renewable energy.

Some possible battery second life applications include:

- Re-use or repackaging of modules or packs with testing for compatibility in vehicle applications;
- Re-use for lower power applications especially DC and home to grid and vehicle to grid, etc.;
- Re-use in industrial situations utilizing DC energy for manufacturing with low voltage use and storage;
- Re-use with alternative power in small farm or school type uses, and as battery backup and stable power source;
- Re-use with alternative power in medium factory or building uses, and as battery backup and stable power source;
- Re-use for grid support, line balancing and backup stabilization.

The nascent second life market for EV batteries has the potential to lower the cost of electro-mobility and enhance environmental protection through materials retention, re-use, and extended battery pack life, leading to value chain enhancements.

3.1.1.7 Crash Tests/Safety

To be sold in the U.S., electric vehicles must comply with all applicable Federal Motor Vehicle Safety Standards (FMVSSs). These include crash avoidance standards, crashworthiness standards, post-crash safety standards and others. FMVSS 305, Electric Powered Vehicles: Electrolyte Spillage and Electrical Shock Protection, addresses propulsion battery electrolyte spillage, intrusion of propulsion battery system components into the occupant compartment, and electrical shock.

The FMVSSs are enforced by the National Highway Traffic Safety Administration (NHTSA), which routinely conducts compliance testing to ensure that the vehicles certified for sale in the U.S. comply with all of the applicable requirements. Vehicles that are noncompliant or vehicles that possess a safety defect are subject to NHTSA's recall and remedy provisions of the Motor Vehicle Safety Act.

3.1.2 Vehicle Components

Key on-board vehicle areas addressed within this roadmap include safety issues associated with internal high voltage cables and on-board wiring, component ratings, and charging accessories; vehicle diagnostics – emissions; and audible warning systems.

3.1.2.1 Internal High Voltage Cables, On-Board Wiring, Component Ratings and Charging Accessories

The advent of the electric vehicle poses unique opportunities and challenges from a safety perspective. In terms of vehicle component standards, the high voltage cables entail the primary conductive media internal to the vehicle. This area does not include the cabling systems commonly used in 12V and 24V systems that form the basic wiring systems in conventional vehicles. Instead, this topic focuses on the systems and subsystems associated with the primary drive mechanisms for the vehicle. For hybrid electric vehicles, this includes the cabling associated with any electricity transferred from the internal combustion engine to the storage device, as well as regenerative braking technology and the charging station. For plug-in electric vehicles, this is only the braking and charging connections to the drive train. Both AC and DC technologies are considered. Concerns over the internal, high voltage cables relate to both the safety of the operator and the integrity and efficiency of the propulsion and storage systems for the EV.

3.1.2.2 Vehicle Diagnostics – Emissions

An issue for plug-in hybrid electric vehicles and hybrid electric vehicles (but not for all electric vehicles), is vehicle diagnostics with respect to the detection of system faults within the vehicle's emissions control system.

3.1.2.3 Audible Warning Systems

Organizations of, and for, persons who are blind or have low vision have expressed concerns that electric vehicles and some hybrid electric vehicles may not be audibly detectable by the blind. Safety standards related to sound emission/audible warning systems can serve to address this concern.

3.1.3 Vehicle User Interface

A reliable, safe customer experience is critical to electric vehicles gaining acceptance in the market place. One step toward improving this experience is using communication tools that are readily identifiable and understood by the vehicle owner and those that service or otherwise interact with the vehicle. Topics addressed in this section include: graphical symbols; telematics – driver distraction; fuel efficiency, emissions, and labeling.

3.1.3.1 Graphical Symbols

Due to the global nature of the industry, the use of universal graphical symbols that are easily understood regardless of the language of the driver will assist in effective communication of such important information as the battery fuel gauge, state of charge, and health. Other important areas include suitable symbols to identify critical battery parts to owners, maintenance personnel, and even first responders.

3.1.3.2 Telematics – Driver Distraction

Telematics is the combination of telecommunication and programmable computerized services to assist drivers with navigation, emergency assistance, convenience features such as remote door locks, climate conditioning, access to internet/cloud services, on-board diagnostics, service reminders, and other infotainment services. This section discusses driver interaction with such information and communications systems, and more specifically the potential for driver distraction from the task of driving.

3.1.3.3 Fuel Efficiency, Emissions, and Labeling

Fuel economy and vehicle emissions are among several factors that consumers will evaluate in deciding whether or not to purchase an electric vehicle. It is therefore important that vehicle labels provide clear and accurate information. As more electric vehicles appear on the market, it will become increasingly important for consumers to be able to compare among different manufacturers and models. Consumers will also want to compare and contrast features and value across the different types of available EVs (BEVs, PHEVs, HEVs) in the same way that they have traditionally evaluated vehicles powered by internal combustion engines.

3.2 Infrastructure Domain

For purposes of this roadmap, the Infrastructure Domain generally encompasses the technologies, equipment, components, and issues that fall within the confines of the charging infrastructure up to and including the connector portion of the charge coupler. The following sections under the Infrastructure Domain, 3.2.1 Charging Systems, 3.2.2 Infrastructure Communications, and 3.2.3 Infrastructure Installation, discuss the relevant issues that fall under these topical areas and why they are important with regards to standardization, harmonization, and conformance activities. The interrelationship of issues within the Infrastructure Domain is illustrated in Figure 3.

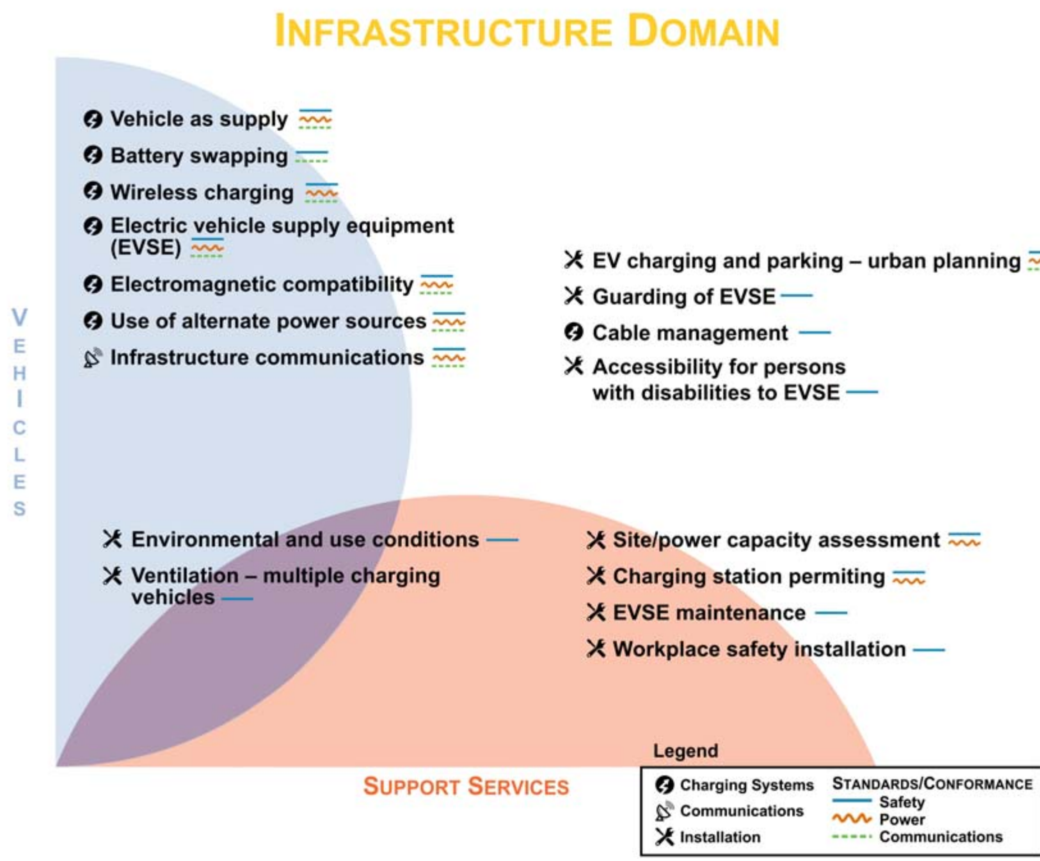

Figure 3: Interrelationship of Issues within the Infrastructure Domain

3.2.1 Charging Systems

In order to promote the development, acceptance and deployment of EVs, and to discourage the imposition of market barriers, it is imperative that plugs, chargers and EVs be interoperable. EV owners must be able to easily recharge their vehicle at their home or office and when traveling long distances within their own state and across state lines. Harmonized standards that assure the interoperability of EVs with the charging infrastructure will do much to help grow the market for EVs, and thus will be in the best interest of EV and EVSE manufacturers, as well as EV users.

Topics addressed in this section include: wireless charging; battery swapping; electric vehicle supply equipment; electromagnetic compatibility; vehicle as supply; and use of alternative power sources.

3.2.1.1 Wireless Charging

Wireless charging is a rapidly developing technology that will lend itself naturally in the promotion and deployment of EVs. Although at this time the standards for wireless charging are not complete, there is a significant interest in this technology. The goal is to be able to park in a charging location or your garage to charge your vehicle without the necessity of physically plugging in your EV. It is important to have harmonized standards for this technology to allow the ease of crossing borders from state to state and country to country.

3.2.1.2 Battery Swapping

The limited range of current plug-in electric vehicles is a major obstacle when it comes to consumer adoption and the migration from traditional internal combustion engine powered transportation solutions to a clean battery powered solution. The current estimated range of full battery electric vehicles is around 80-120 miles with a battery weight of around 550-600 pounds. In a plug-in hybrid electric vehicle, range can be extended via a gas-powered generator. In general, the current range of PEVs on battery power alone is satisfactory for most daily commuter driving, but it does not provide the ability to drive long distances, hence the need for range extension. Accordingly, there is a need for a supporting infrastructure of charging networks covering homes, offices, parking, shopping and industrial areas, and highways where PEVs can plug-in to recharge.

An alternative approach to addressing the range extension issue is via a network of battery swapping (switching) stations (BSS). A BSS is an electro-mechanical installation of robotics, electrical and mechanical drives used for the switching of batteries for electric vehicles and that may include battery charging devices and telecommunication ports. This technology exists today and has been used in niche segments for many years, enabling the replacement of a depleted battery with a fully charged one in less than 5 minutes. The fully automated process removes the battery from the vehicle and moves it to a battery rack, so the battery can be charged in optimal conditions. A fully charged battery is then taken from the battery rack and inserted into the vehicle. Battery swapping stations could be located along all key highways or major roads, thus enabling electric vehicles to drive for extended ranges. Battery swapping stations are currently being mass deployed in Israel, Denmark, and China.

Battery swapping technology would require removable batteries with common interfaces that connect with the battery outside the vehicle. EV batteries are currently very heavy, which requires that they be carefully handled. Therefore, removable batteries will require a common mechanical interface to lock and remove the battery from the vehicle by actuation of "twist-like" devices by external actuators which are part of a switching station. Other issues pertinent to common battery packs and modules include electrical interface, cooling integration, data transfer integration and dimensions.

3.2.1.3 Electric Vehicle Supply Equipment (EVSE)

Power Quality

Plug-in electric vehicles require both the electric grid and the vehicle charger to be reliable, as the power quality of one depends on the power quality of the other. Coordinating the electric utility grid characteristics and acceptable levels of power quality for vehicles and vehicle chargers allows manufacturers and utilities to ensure that PEV users achieve a reliable charging experience.

EVSE Charging Levels/Modes

One of the most critical components to electric vehicle adoption is the ease and efficiency by which the vehicle can be recharged, and the availability of charging facilities. The most available means of charging an electric vehicle is to use a standard grounded electrical receptacle in accordance with NEC® Article 625 requirements. This is most practical at home where receptacle outlets are readily available and downtime for the vehicle potentially allows the longest charging period throughout the day. Charging at higher AC voltages, or using DC voltages, can provide a faster charge. These AC voltage levels are available in homes, as well as municipalities, workplaces, and retail locations. DC chargers and high power AC supply equipment can provide high power charging, reducing the time it takes to charge a vehicle.

Off-Board Chargers and Supply Equipment

Infrastructure equipment consists of off-board chargers, off-board charging stations, or portable EV cord sets (also referred to as charge cables). Off-board chargers supply DC power to a vehicle in order to charge the on-board storage battery directly, whereas off-board charging stations and portable EV cord sets supply AC power to a vehicle's on-board charger. Vehicles may be designed for use with both types of infrastructure equipment. On-board systems and controls are required to maintain the proper charge path such that AC voltages are not applied to the battery and the like.

Infrastructure equipment is provided with a system of protection that is used to monitor ground connections or isolation of the charging circuit from the user. These systems monitor the infrastructure device as well as the vehicle through the conductive connection. The protection systems provide a portion of the control for the charging function and shutdown the infrastructure equipment in the event of a loss of the protective elements associated with that system of protection (ground or isolation).

EV Couplers

A critical user component required for recharging plug-in electric vehicles is the EV coupler, which consists of a vehicle connector and a vehicle inlet. This vehicle connector and vehicle inlet combination (coupler) provides a conductive path for power from the charging infrastructure equipment to the vehicle, and assists the infrastructure equipment with safety checks, communication, and other aspects associated with safe recharging of the vehicle.

Ideally, electric vehicle operators should be able to use any available charging station to recharge their vehicle. This interoperability is governed by the electric vehicle charging systems including the vehicle couplers. For these reasons, standardized EV couplers are vitally important in facilitating public adoption of EVs, especially when multiple vehicle models are involved.

The EV coupler is also instrumental in protecting people from the risk of electric shock. This includes the vehicle owner, as well as other people in the area that may contact the electric vehicle or the EV coupler. The EV coupler also protects the vehicle, by guarding against mismatching of the vehicle connector and vehicle inlet, and providing for the correct communication and pilot controls via an expected charge protocol. Safety standards provide the minimum requirements necessary to protect the vehicle owner, general public, infrastructure, garage, and charging site while the vehicle is charging.

With standardized couplers, an EV driver would be familiar with one type of EV connector and would not have to worry about matching a connector to their particular vehicle make and model. Standardization would also reduce attempts to modify equipment, or provide adapters to convert equipment, which could adversely affect the safety of the charging system. Harmonized standards (national, regional, international) would be beneficial, so that all EV couplers and electric vehicles would function in the same manner and provide similar protection.

3.2.1.4 Electromagnetic Compatibility (EMC)

The concept of EMC is to protect both the communications channels and the electrical circuits used in charging and operating the vehicle. The focus is to limit or control electromagnetic emissions by both the vehicle and charging station devices to keep them within tolerable limits for other nearby devices. EMC standards help maintain the integrity of the EV system as a potential emitter and "good citizen" of the electric grid, as well as protecting the vehicle and charging station from other emitters on the grid. This is necessary to maintain the safety and interoperability of the devices within the charging environment.

3.2.1.5 Vehicle as Supply

The topic of vehicle as supply describes the vehicle serving as a power source for other than vehicle applications. Reverse power flow (RPF) is when the EV transfers power to off-board equipment as further described below.

Pure reverse flow is very useful for powering loads at a remote site; this capability is called Vehicle to Load (V2L). An EV can also use pure reverse power flow for providing a "jump start" to another EV; this capability is called Vehicle to Vehicle (V2V). And pure reverse flow from an EV can be used to provide emergency backup power for a home following a loss of grid power; this is called Vehicle to Home (V2H). Because these are all off-grid applications, the on-board or external inverter must regulate both the voltage and the frequency and it is the connected loads that determine how much energy flows from the vehicle battery.

When a vehicle provides reverse power flow into a live electric grid this is called Vehicle-to-Grid (V2G). A small, modular storage device connected to the grid is considered to be a Distributed Energy Resource (DER). The grid-connected EV that is capable of reverse power flow is a DER device. The real value of an EV to the grid is its ability to serve as a DER device and provide precisely controlled bidirectional power flow – not just reverse flow. The bidirectional converter can be located on-board the vehicle or externally in the EVSE. When the grid-tied bidirectional converter is providing power to the grid it must operate as a current source, synchronized to the grid voltage and frequency. The grid-tied bidirectional converter can be commanded to deliver a precise forward or reverse power flow. If there is a power failure, the inverter must automatically turn off. This is for the safety of workers that may be repairing downed lines.

The term V2G has become associated with the concept of an aggregator coordinating the power flow of many EVs to provide frequency regulation for the grid. This is only one of many ways that an EV can serve the bulk grid and the distribution system as a DER. An EV with DER capability can be used solely within a home by a home energy management system to manage the power demand of the home on the external grid. This is not a V2H application because the home loads are still connected to a live grid. However, a grid-tied inverter system can be configured to automatically disconnect the home from the grid and switch from V2G to V2H operating mode following a grid power failure. This is routinely done today with grid-tied solar PV inverter systems.

An EV could route power from an on-board inverter to a vehicle-mounted panel with NEMA receptacles. This would be very convenient for directly connecting tools or appliances to the panel for V2L or using a cord set for V2V. The EV could also be connected to the home through a transfer switch in the same manner as any other portable genset to provide V2H capability. The EV to EVSE connection would be used for V2G.

An external inverter would use the EV to EVSE connection and extract DC power from the vehicle battery to generate the AC power. A premises-mounted EVSE could be used for V2G and V2H modes with automatic switching. A portable unit could be used for V2L and V2V applications.

3.2.1.6 Use of Alternative Power Sources

EVs support and complement the increased possibility of an infrastructure with distributed generation of power, and direct connection of power sources to the EV for charging purposes. This includes efficiency benefits of DC generation and DC use, without losses associated with conversion to and from AC, for example use of photovoltaic (PV) for direct DC charging of electric vehicles. It also allows the EV battery to serve as a storage device for alternative energy systems, for example solar power generated during the day or wind power generated at night, which can be reclaimed later as needed.

3.2.2 Infrastructure Communications

The charging of EVs represents a significant additional load on the grid providing both risks and opportunities for service providers and consumers. At a minimum, consumers want access to a ubiquitous charging infrastructure that enables them to charge their EVs safely and quickly at the cheapest possible rate. Energy Service Providers want to be able to push charging to off-peak hours to protect grid assets.

Additionally, value-added services such as demand response/load control, pricing, locating and reserving charging stations, reverse energy flow, and charge management can provide further benefits. To advance a truly smart grid that can accommodate EVs, it is necessary that communication among the various entities involved be enabled to maximize the services offered and the benefits that EVs can deliver.

Topics discussed in this section include: actors, charging locations, and other factors governing communications; communications requirements for EV charging; communication of standardized EV sub-metering data; and communications standards.

Actors, Charging Locations, and Other Factors Governing Communications

An *actor* is an entity that serves as one end point of communications. For example, when an EV communicates with an EVSE, the two actors are the EV and the EVSE. The primary actors involved in EV-related communication are expected to be the: (1) EV driver, (2) EV, (3) EVSE, (4) Energy Service Provider (ESP), (5) intelligent premises or commercial/public infrastructure, (6) End Use Measurement Device (EUMD), and (7) EV Services Provider (EVSP). A detailed listing of actors and the types of communications between them is set forth in Appendix A.

The actors and communication methods involved in EV charging may vary, depending on criteria such as the location of charging (home, commercial premises, or public charging); the EV-related infrastructure (communications-capable or not); the type of charging (AC/DC/Wireless); the charging provider (utility, corporation, municipality, EV Services Provider, etc.); and the requirements for authentication, authorization, accounting, and billing of the charging session.

Figure 4 shows a sample communications-oriented architecture containing the primary actors, including three different locations where charging may occur. Typically, there is an entity that manages the energy flow within each location and acts as an interface between the Energy Service Provider and the various charging locations.

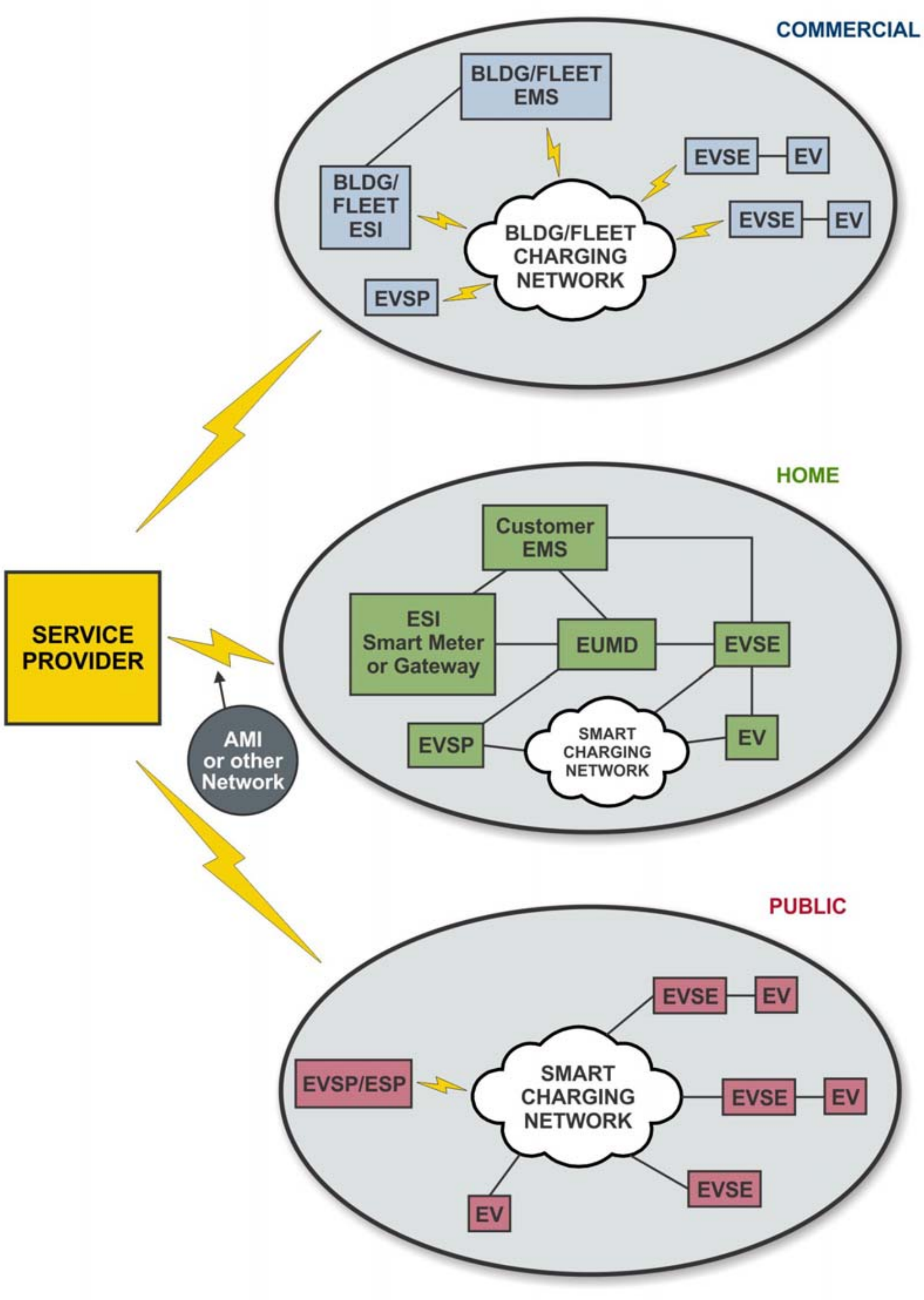

Figure 4: Sample Communications-Oriented Architecture for Commercial, Home, and Public Charging

In a home, an Energy Management System (EMS) acts as an analog of a building EMS and controls all the energy loads in the home, including EVs. While the external communication with the Energy Service Provider uses a standard Energy Services Interface (ESI), communication between the EMS and the internal charging infrastructure takes place via a Home Area Network (HAN). Optionally, an EV Services

Provider may manage the EV portion of the load, leaving the EMS to handle the remaining loads such as air-conditioning.

In the case of a commercial/industrial building, an EMS may be the entity managing the energy flow. It communicates with the ESP via a standard ESI, and with the building's charging infrastructure via some internal communications mechanism (e.g., BACnet).

For public charging stations, an EV Services Provider manages a network of EVSEs and provides charging availability to EV drivers. The EVSP communicates with the ESP using a standard protocol such as SEP 2.0 or ESPI, and may act as an aggregator, providing a single communication point with the ESP for all the EVSEs in its purview. It is desirable to create and/or harmonize communication standards in order to provide services specific to public charging such as finding and reserving charging stations.

Communications Requirements for EV Charging

There are various communication requirements for charging of EVs under different use cases (home, commercial, public) and metering options, each with different levels of complexities.

In general, non-smart charging at home is one of the simplest scenarios from a communications perspective, and provides ready benefits and motivation for the installation of EVSEs in the home. However, home charging rapidly becomes more complex if smart charging capabilities exist and charge management and/or demand response is implemented. Further communication complexities come into play if the EV is to be used as a supply source providing reverse power flow to the home or grid.

Commercial applications often involve multiple vehicle charging scenarios with load balancing and sequencing in order to meet business application requirements and minimize costs. Accurate, real time coupling of state of charge (SOC) assessment, business application requirements, and service provider demand response load control is essential.

Public charging has different communication requirements including the need to quickly and easily locate, price compare, and reserve charging stations on the fly. Additional complexities are also introduced due to the need to authenticate, authorize, and bill the user, especially when crossing over different service territories.

The following briefly describes a number of the requirements for information/communication exchange, not all of which are germane to each use case.

Finding and Reserving Charging Stations: EV drivers charging outside their home need to easily find and optionally reserve an available, compatible charging station. In-vehicle dashboard systems, portable navigation devices, smart phones, and personal computers need to communicate with entities that can provide these services.

Charging Related Information Retrieval: EV drivers need to retrieve information about the current SOC of their EV and an estimate of how long charging may take. Based on this information, the driver can make an informed decision about where to charge, relieving range anxiety. This information is available in the EV and needs to be communicated to the driver via standard mechanisms.

Pre-Charging Information Exchange: In order for charging to take place, an EV must be physically associated with an EVSE. At that point, charging parameters such as direction of energy flow, start and end time of charging, price, and EV/driver authentication information need to be communicated between the EV, EVSE, and grid.

During a Charging Session: For billing purposes, it is critical to accurately measure the energy being provided to the EV and communicate this to the EVSP/ESP, optimally in real time. Charge management including battery SOC is important. Energy Service Providers may need to act in real time during peak demand situations by providing incentives to EVs to reduce the amount of energy consumed (demand response load control).

Notifications: The EV driver may optionally opt-in to receive notifications when charging is completed or ends due to a fault. Such information needs to be communicated from the EV/EVSE to the driver.

Post-Charging: At the end of a charging session, the EV driver/owner must be billed. This may involve communications with a credit card processor, communication between an EVSP and an ESP, or communication between two EVSPs (e.g., when roaming).

Communication of Standardized EV Sub-metering Data

Though not required for charging purposes, the measurement of EV energy consumption is necessary to provide customers certain value added services related to EV and HAN energy usage information and control. Along with demand response load control (DRLC), discrete measurement of an EV along with time of use (TOU) tariffs is necessary to push charging to off-peak times, lowering customer costs and addressing issues related to the integration of renewables.

Regulatory issues and business cases will determine how metering of EVs is implemented. This would include whether End Use Measurement Devices (EUMDs) need to be revenue grade in order to be used for customer billing; who is allowed to own the EUMDs; who bills the customer; and how they communicate. EUMDs can be separate meters (and therefore most likely to utilize existing metering communication such as utility Advanced Measurement Interface (AMI) systems), probably necessitating a second panel and service account. EUMDs could also be sub-meters, installed on a branch circuit of the premises meter and necessitating a subtractive billing process to apply special rates. Sub-meters could be located anywhere from the branch circuit to within the EVSE or EV itself.

Communications Standards

In order to successfully communicate the information required in the above scenarios, multiple actors, protocols, and communication media may be involved. Each primary actor may be capable of communicating via multiple methods. For example, an EV may be able to communicate with an EVSE using power line communication (PLC) over the physical link between them. The EV may also be able to communicate with an EV Telematics Provider using telematics communication over wireless cellular radio (2G/3G/4G).

Due to the number of actors involved and services being offered, as well as the plethora of communications technologies in service, it is critical to standardize these communications as much as possible to provide ease of entry into the market while also allowing widespread and consistent charging capabilities to drivers without adversely impacting the grid. Communications interoperability is a critical component of a smart grid.

3.2.3 Infrastructure Installation

Installing electric vehicle infrastructure can be a unique challenge for communities. Appropriate codes and standards to guide infrastructure installation will enable safe and effective deployment. Several key areas must be addressed to streamline and more effectively deploy EV infrastructure including site/power capacity assessment; EV charging and parking - urban planning; charging station permitting; environmental and use conditions; ventilation – multiple charging vehicles; guarding of EVSE; accessibility for persons with disabilities to EVSE; cable management; EVSE maintenance; and workplace safety.

3.2.3.1 Site/Power Capacity Assessment

Electric vehicle supply equipment (EVSE) for vehicle charging places an additional demand on the electrical system where the capacity to supply the load must be verified and provided. A site assessment is typically performed by an electrical contractor to verify capacity and ensure the existing service or system will not be overloaded.

3.2.3.2 EV Charging and Parking - Urban Planning

In order to accommodate increased numbers of electric vehicles in urban settings, considerations are needed with regards to facilities' charging and parking provisions. As parking requirements are sometimes established by standards, codes, and/or regulations for various building types, insights for EVs may be gleaned therein and potentially incorporated as part of revised versions. Traditionally determined locally, enforcement of parking space use is more complex, involving considerations of whether parking is for electric vehicles generally or only for charging and, if so, for what duration.

3.2.3.3 Charging Station Permitting

To enable the widespread acceptance of electric vehicles, it is important that charging station installations be safe and meet electrical and building code requirements. These requirements help assure that personal injuries, fires, and other hazards are avoided through proper installations and are managed through existing building plan approval and inspection processes. The existing safety system relies on product safety standards and certification, installation and building codes and standards, and permits and inspections – all three of which are essential to the safe functioning of the system.

Residential Installation: Permitting and inspection of a residential charging station is likely the only time a jurisdiction has the opportunity to determine that the charging system is correctly installed to ensure life safety for residents and to minimize fire or other risks to the property. Before approving a residential installation, jurisdictions may require information on the system being installed, the method of installation and any standards or product requirements relating to installation. Information on the licensing or qualifications of the installer may also be required. There may be differences in permitting requirements for single- and multi-family dwellings depending upon the jurisdiction.

Commercial/Public Installation: The permitting and inspection of a commercial or public charging station has greater potential to impact a larger population than a residential installation, but the jurisdiction will likely have greater opportunity to monitor the system through common annual building inspections conducted to assure compliance with the local fire code. As with residential installations, jurisdictions may require product, installation, and installer information to ensure safety.

3.2.3.4 Environmental and Use Conditions

Electric vehicle infrastructure equipment may be used in a wide variety of conditions. Environmental factors that may affect the safety, durability, performance or life of the electric vehicle infrastructure equipment include ambient temperature, precipitation, humidity, corrosive agents, and altitude.

Temperature range, including consideration of extremes of hot and cold exposure, may affect the ability of the product to function in the expected manner. Ability to prevent ingress of precipitation or other contaminants such as dust may degrade the insulation or performance of equipment. Where applicable, the equipment's ability to withstand the effects of icing and/or de-icing may be important. High humidity conditions may also affect equipment insulation or performance.

Infrastructure equipment also may be exposed to potentially corrosive agents such as salts whether through installation in proximity to bodies of salt water or through exposure to anti-icing salts applied to roads.

Hazardous or classified locations are terms used to identify installations where fire or explosion hazards may exist because of the presence of flammable or combustible gases or vapors, or other potential sources of fire and/or explosion hazards. As it relates to electric vehicles, these may be relevant both with respect to the existing presence of such hazards from outside sources (for example, at a fuel station), and for the generation of such hazards through the electric vehicle charging process, if applicable based upon the battery technology that is employed.

3.2.3.5 Ventilation - Multiple Charging Vehicles

Ventilation concerns must be addressed if charging stations are installed in enclosed areas such as parking garages located in or under commercial buildings or multi-family residential dwellings. Public officials and building operators will be concerned both with the possibility of off-gassing and heat generation during charging operations, both of which may affect ventilation standards or codes. Vehicle charging locations may be designated in, or only permitted for, ventilated areas of enclosed buildings.

3.2.3.6 Guarding of EVSE

The guarding of EVSE is an important issue encompassing physical and security protection for equipment. Appropriate guarding of EVSE will enhance protection for users, facilitate safe charging experiences, and lower risks in situations of vehicular collisions.

3.2.3.7 Accessibility for Persons with Disabilities to EVSE

Design considerations for EVSE must also take into account accessibility requirements in the building codes, as well as state and federal accessibility regulations including the Americans with Disabilities Act and the Fair Housing Act.

3.2.3.8 Cable Management

Cord connected EVSE poses several challenges with regards to safety and theft especially within the public arena. Safety aspects include possible tripping hazards and concerns about vehicle drive-aways while still plugged in. Copper cables within EVSE offer tempting theft opportunities with resulting safety implications.

3.2.3.9 EVSE Maintenance

While it is expected that most EVSE will require relatively little maintenance, it is considered best practice to consistently follow a maintenance regimen to reduce safety risks and extend the service life of EVSE. EVSE manufacturers typically provide recommended maintenance practices as part of service manuals, and other information is available to provide guidance with regards to maintenance of EVSE and electrical equipment in general.

3.2.3.10 Workplace Safety

Safety Programs and Safe Work Practices: Safety in electrical construction, installation, and maintenance must be addressed proactively across a broad spectrum of workplace tasks and hazards. Safety in construction requires establishing sound and effective safety principles and contractor safety programs. Best practices for such programs include having in place a policy with goals, a plan, methods of implementation, measurements, record-keeping, and ongoing auditing and assessment. Safety requires communication, coordination and cooperation between employees and the employer as it is a shared responsibility. Ultimately, employers are responsible for developing and maintaining effective safety programs and for ensuring that employees implement safe electrically-related work practices.

Shock, Arc-Flash, and Arc Blast Protection: Workplace safety for electrical workers requires compliance with applicable electrical safety related work requirements. Work generally should always be performed in an electrically safe work condition, and installation and maintenance should not be performed on equipment or systems that are energized. Energized work must be justified and it must be proven that it is not feasible to de-energize the system or that doing so would introduce additional or increased hazards. In situations where justified energized work must be performed, appropriate personal protective equipment (PPE) must be worn. Effective safety-related work practices and principles must be integrated into the planning stages and installation of electrical work, as well as into initial planning and design of EVSE installations.

3.3 Support Services Domain

For purposes of this roadmap, the Support Services Domain generally includes the supporting peripheral activities, both under incident response and normal operating conditions, necessary to the well being of the broad electric vehicle and infrastructure environment. Standards, and education and training programs for service personnel, are the primary focus with safety the paramount concern.

Incident response

Incident response is the activity performed by service providers when the EV has been damaged or disabled as result of an incident either on the road or at a garage/parked location where vehicle service is not normally performed. Incident response may be prompted by a breakdown, involvement in an accident, or the EV being at the scene of an incident, such as a fire, where a building or EV charging equipment may be involved and there is a need to stabilize or remove the EV to avoid its further involvement.

Standards and training can help ensure the safety of emergency responders as they stabilize EVs in the field, provide medical service to and extract trapped passengers from them, extinguish fires, and remove vehicles from the roadway. When EVs are plugged into chargers during incidents, standards and training can also provide information regarding the safe disconnecting of chargers from power sources.

A broader issue that was raised at the second ANSI EVSP plenary meeting was disaster planning and the need for standards and/or first responder programs to deal with emergency evacuation from urban areas in a scenario where there are potentially large numbers of electric vehicles on the road interacting with the grid. This is viewed as a long-term planning issue to be considered in future discussions.

Normal operations

Normal operations include driving and charging of EVs, and servicing and maintenance activities performed at service locations, including dealerships, service garages, fleet lots, and at vehicle owners' residences.

Standards and training can help ensure the safety of service technicians and vehicle owners as they operate or service EVs every day including performing charging functions, working on EV motive systems, and changing out batteries.

The following issues under the topical area of Education and Training outline important considerations within the Support Services Domain for EVs and supporting infrastructure: vehicle emergency shutoff including labeling of high voltage batteries, power cables, and disconnect devices; labeling of EVSE and load management disconnects; original equipment manufacturer (OEM) emergency response guides;

safe battery discharge/recharge in emergencies, and workforce training. The interrelationship of issues within the Support Services Domain is illustrated in Figure 5.

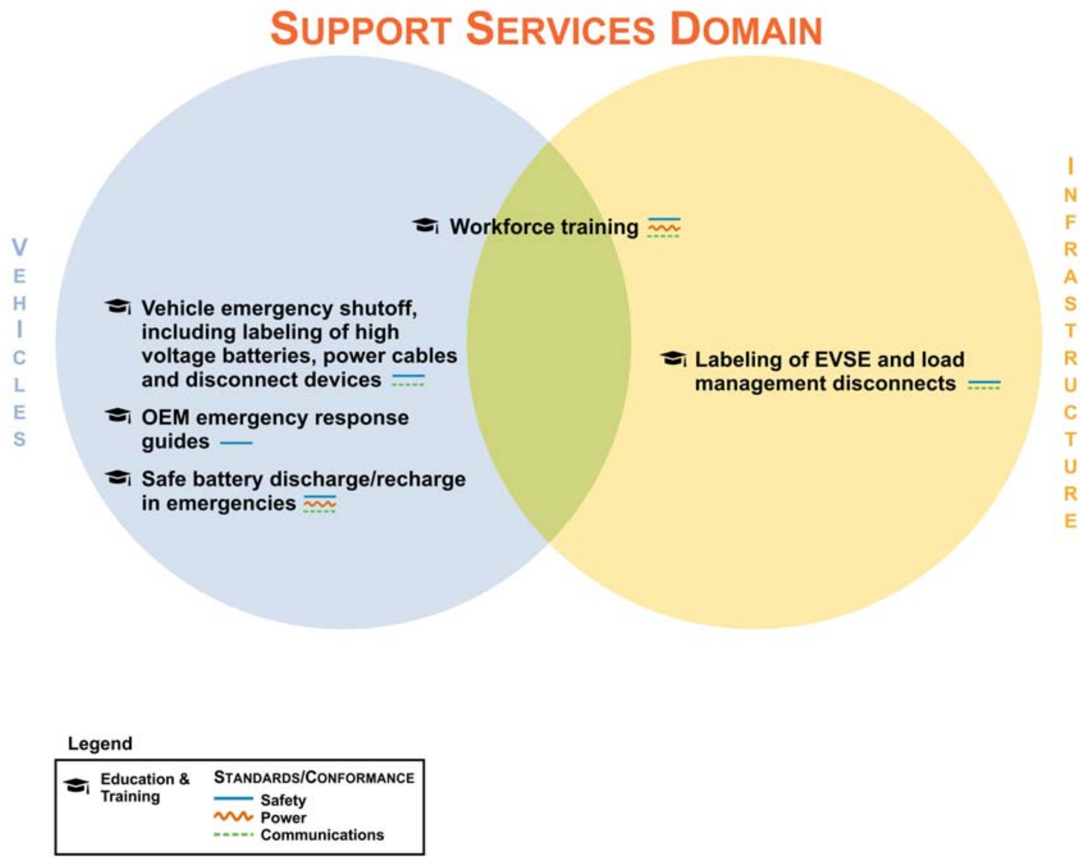

Figure 5: Interrelationship of Issues within the Support Services Domain

3.3.1 Education and Training

Education and training regarding the unique characteristics of EVs and their support equipment is needed for the various trades including service technicians, tow operators, emergency responders (including fire service, emergency medical services, and law enforcement), fire investigators, incident investigators, and electrical inspectors and installers. Some education is required for vehicle owners including fleet operators.

Emergency responders to incidents involving electric vehicles need to know how to safely stabilize crashed vehicles; extract vehicle occupants; handle EV batteries; remove disabled vehicles from the scene; and, handle incidents involving EVs that are being charged at public or private EVSEs.

Vehicle service technicians need to know how to identify power components in EVs (including batteries, cables, and disconnects) and how to safely remove, install, store, and recycle EV batteries during non-emergency operations.

Electricians and electrical inspectors need to know how to properly install EVSE and demonstrate to building owners and homeowners how to operate EVSE and any associated load management equipment.

Fleet operators and vehicle owners need to know how to charge their vehicles and how to properly disable the EV power source to their vehicle once charging is completed.

3.3.1.1 Vehicle Emergency Shutoff, Including Labeling of High Voltage Batteries, Power Cables, and Disconnect Devices

Emergency responders need to be able to quickly and easily identify and properly handle high voltage EV batteries, power cables, and disconnect devices during emergency situations. Clear safety markings would help to protect emergency responders, law enforcement, tow operators, and vehicle occupants from electrical shock hazards during passenger extrication and post crash vehicle movement and servicing.

3.3.1.2 Labeling of EVSE and Load Management Disconnects

During emergencies involving EVs that are connected to charging stations, either in public or private locations, emergency responders need to understand how to shut down and disconnect the equipment. Labeling, especially graphics, would aid in quickly identifying devices and disconnect locations.

When EVSEs are used in conjunction with load management equipment, locations and connections to the load management equipment should be easily identifiable and have ready access. In these cases, the EVSE may be energized through a load management device which may measure other loads on a service or feeder to determine whether there is adequate capacity to supply power to an EVSE.

Another configuration may permit the sharing of a 240-volt branch circuit with another 240-volt appliance instead of being directly connected to a dedicated branch circuit with its own disconnecting means such as a circuit breaker or fuse. The load management device in this configuration would only permit EVSE operation when other loads are not present on the branch circuit.

3.3.1.3 OEM Emergency Response Guides

Vehicle manufacturers produce emergency response guides (ERGs) which provide instructions and schematic details of safety procedures for their vehicles. These show access points, disconnect locations, and chassis dismemberment locations valuable to first responders and rescuers particularly when extrication of a vehicle passenger is required.

3.3.1.4 Safe Battery Discharge Recharge in Emergencies

Directions and procedures for the safe discharging / recharging of EV batteries following an incident is important information for emergency responders. The ability to quickly and safely discharge / recharge an electric vehicle on the road would facilitate removal of the vehicle from the scene and possibly allow it to leave under its own power. This information would be particularly beneficial for tow operators and roadside assistance providers.

3.3.1.5 Workforce Training

In addition to the training requirements described above, as the electric vehicle market grows and creates jobs, there will be an increasing need for widespread occupational training and education to support the life cycle of EVs and associated infrastructure.

4. *Gap Analysis of Standards, Codes, Regulations, Conformance Programs and Harmonization Efforts*

Section 4 presents the details of the gap analysis of standards, codes, regulations, and conformance programs, be they existing or in development, with particular focus on those that are pertinent to the rollout of electric vehicles in the United States. This assessment also included a review of relevant harmonization activities underway.

In this context, a gap refers to a significant issue – whether it be related to safety, performance, interoperability, etc. – that has been identified and that should be addressed in a standard, code, regulation or conformance program but no standard, code, regulation or conformance program currently is published or known to exist that adequately addresses the issue. Gaps can be filled through the creation of entirely new standards, code provisions, regulations, or conformance programs, or through revisions to existing ones. In some cases work may already be in progress to fill the gap.

A partial gap refers to a situation where a significant issue has been identified that is partially addressed by an existing standard, code, regulation or conformance program.

No gap means there is no significant issue that has been identified at this time or that is not already adequately covered by an existing standard, code, regulation or conformance program.

Note: If no information is provided in the sections that follow on conformance programs or harmonization efforts, it means that either the issue was not addressed or no gap was identified at this time with respect to the issue.

Additional details regarding the identified standards, codes, regulations, and conformance programs described in this section can be found in the ***ANSI EVSP Roadmap Standards Compendium*.**

4.1 Vehicle Domain

Terminology

There are published standards devoted to general technical terms as well as published standards specific to electric vehicle terminology. The goal should be to encourage the use of consistent terminology related to electric vehicles.

- ISO 8713, Electric road vehicles – Vocabulary, published in 2005, establishes a vocabulary of terms used in relation to electric road vehicles and focuses on terms specific to electric road vehicles.
- SAE J1715, Hybrid Electric Vehicle (HEV) & Electric Vehicle (EV) Terminology, published in 2008, is intended as a resource for those writing other electric vehicle documents, specifications, standards, or recommended practices. SAE J1715 is in the process of being split into two parts

among the SAE Hybrid Committee and SAE Battery Committee. The new standard will be designated parts 1 and 2.

Partial Gap: **Terminology.** There is a need for consistency with respect to electric vehicle terminology.

Recommendation: Complete work to revise SAE J1715. ***Priority:*** Mid-term. ***Potential Developer:*** ISO, SAE.

4.1.1 Energy Storage Systems

4.1.1.1 Power Rating Methods

There are two standards under development that address power rating methods for electric vehicles:

- SAE J2907, Power rating method for automotive electric propulsion motor and power electronics sub-system, which provides a test method and conditions for rating the performance of electric propulsion motors as used in hybrid electric and battery electric vehicles; and
- SAE J2908, Power rating method for hybrid-electric and battery electric vehicle propulsion, which provides a test method and conditions for rating performance of complete hybrid-electric and battery electric vehicle propulsion systems reflecting thermal and battery capabilities and limitations.

Gap: **Power rating methods.** Standards for electric vehicle power rating methods are still in development.

Recommendation: Complete work to develop SAE J2907 and J2908. ***Priority:*** Mid-term. ***Potential Developer:*** SAE.

4.1.1.2 Battery Safety

EV battery safety standards development has been identified as a priority by standards development organizations including IEC, ISO, SAE and UL, as well as regulatory bodies such as NHTSA. As a result, a number of electric vehicle battery and related safety standards have been published or are currently under revision or development. A breakdown of this effort by organization follows:

IEC

- IEC 62660-2, Secondary batteries for the propulsion of electric road vehicles – Part 2: Reliability and abuse testing for lithium-ion cells, was published in 2010. Although not specifically identified as a safety standard, it does include tests which address safety issues such as short circuit and overcharge.

ISO

- ISO 6469-1, Electric road vehicles – Safety specifications – Part 1: On-board rechargeable energy storage system (RESS), published in 2009, provides general safety criteria to protect persons within and outside of the vehicle and applies to batteries and other RESS.
- ISO 6469-3, Electrically propelled road vehicles – Safety specification – Part 3: Protection of persons against electric shock, published in 2001 and currently under revision, addresses electrical safety of the RESS within the overall vehicle.
- ISO 12405-1, Electrically propelled road vehicles – Test specification for lithium-ion traction battery packs and systems – Part 1: High-power applications, was published in 2011. It is primarily focused on performance. However, it does contain tests that pertain to lithium-ion battery safety such as short circuit, overcharge, and over discharge tests.
- ISO 12405-2, Electrically propelled road vehicles – Test specification for lithium-ion traction battery packs and systems – Part 2: High-energy applications, is currently under development. It is similar to its Part 1 counterpart for high power applications and contains tests related to lithium-ion battery safety.
- ISO 12405-3, Electrically propelled road vehicles – Test specification for lithium-ion traction battery packs and systems – Part 3: Safety. Work has begun on this standard which will be the ISO safety standard for lithium batteries for EV applications.

SAE

- SAE J1766, Recommended Practice for Electric and Hybrid Electric Vehicle Battery Systems Crash Integrity Testing, was published in 2005 and is currently under revision. It specifically addresses electric vehicle safety concerns resulting from a vehicle crash event.
- SAE J2464, Electric and Hybrid Electric Vehicle Rechargeable Energy Storage System (RESS) Safety and Abuse Testing, recently revised in 2009, provides a series of tests with which to determine an RESS response to a potential abuse condition.
- SAE J2929, Electric and Hybrid Vehicle Propulsion Battery System Safety Standard Lithium-based Rechargeable Cells, was published in 2011. Currently under revision, this standard defines a minimum set of acceptable safety criteria for a lithium-based rechargeable battery system to be considered for use in a vehicle propulsion application as an energy storage system connected to a high voltage power train.

UL

- UL 2580, Batteries for Use in Electric Vehicles, was published as an Outline of Investigation in 2009, and as ANSI/UL 2580 in October 2011. This standard evaluates the cells, cell modules and battery pack's ability to safely withstand simulated abuse conditions. The standard is non-chemistry specific and includes construction requirements and tests to address safety of the electric energy storage assembly and modules which can consist of batteries and/or electrochemical capacitors.

NHTSA

- NHTSA FMVSS 305, Electric Powered Vehicles: Electrolyte spillage and electrical shock protection. Last revised in 2011, it is a set of requirements intended to reduce deaths and injuries during a crash, which occur because of electrolyte spillage from propulsion batteries, intrusion of propulsion battery system components into the occupant compartment, and electrical shock.

There is some movement to develop a Global Technical Regulation (GTR) under WP.29 on electric vehicle safety with batteries as a subset. At the November 2011 session of WP.29, NHTSA, Japan and the European Commission proposed a road map for the establishment of a GTR for electric vehicles, which was endorsed by WP.29. A new IWG is expected to be formed in early 2012 to begin work to develop the GTR, which would apply to all types of hybrid and full battery electric vehicles, their batteries, and other associated high risk components. To the extent possible, the GTR will include performance-based requirements and testing protocols designed to allow for innovation, while ensuring that the unique safety risks posed by electric vehicles are mitigated. The GTR will address the safety of high voltage electrical components, including lithium-ion and other types of batteries, their performance during normal use, after a crash event, and while recharging at a residence or other charging station.

Although there has been active work in the battery safety standards area, the committee identified two gaps that need to be addressed.

Delayed battery overheating events

All of the current tested failure modes of battery systems can be classed as "real time" with regard to outcome. If a European Council for Automotive R&D (EUCAR) hazard level of greater than 2 happens – the EUCAR rating system is used in SAE J2464 – it is assumed that it happens within minutes or a few hours at most. It is now known that some faults that can create EUCAR 2 or higher events may not surface for days or even weeks. This possibility introduces a new hazard potential that could surface at any time unless expediently dealt with in a safe manner. Some of these scenarios are easily recognized and dealt with such as in vehicle accidents and with faulty chargers or battery management systems. Scenarios that are less obvious or detectable are internal partial pack circulating currents that escalate over time to dangerous thermal states. Stray currents occurring in sub sections of a pack that are intermediate in value between zero and hard shorts can evolve and generate excessive temperatures.

Gap: **Delayed battery overheating events.** The issue of delayed battery overheating needs to be addressed.

Recommendation*:* Address delayed battery overheating events in future revisions of SAE J2929. ***Priority:*** Near-term. ***Potential Developer:*** SAE.

Loss of control/dual mode failure in the battery

NHTSA has recognized this particular failure mode which can best be characterized as a double fault condition in the battery system. Some examples of loss of control/dual mode failure events would include: a failure of overcharge protection when the battery is overheated, overheating during a crash event, or a cell thermal runaway event within the battery. SAE J2929 currently focuses on single point failures. NHTSA has plans to research these types of double fault events for consideration in future rulemaking, and has awarded research grants to SAE among others. SAE TEVVBC1 plans to integrate the results of this research into future revisions of SAE J2929.

Gap: **Loss of control/dual mode failure in the battery.** The issue of double fault conditions in the battery needs to be addressed.

Recommendation: Future revisions of SAE J2929 should address loss of control/dual mode failure events such as a failure of overcharge protection when the battery is overheated, overheating during a crash event, or a cell thermal runaway event within the battery. ***Priority:*** Mid-term. ***Potential Developer:*** SAE.

4.1.1.3 Battery Testing - Performance and Durability

The principal areas of interest relating to standards for battery performance and durability testing are as follows:

Cell level performance testing: Specifically in the IEC realm, there are multiple standards for defining and measuring common performance characteristics, with emphasis on the loading conditions expected in electric vehicle or hybrid electric vehicle applications.

Pack level performance testing: Specifically, in the ISO 12405-1 and 12405-2 standards, attention is given to the distinction between high energy and high power applications. These also attempt to define and measure common performance characteristics based on EV or HEV applications.

There is a need to focus on harmonization of key battery performance parameters for electric vehicle applications. For example: “12kWh capacity” alone does not provide sufficient information due to varying methods of measuring and calculating battery capacities. This is particularly key at the cell level, as the cells are the primary determination to battery charge/discharge currents and capacities.

Durability and environmental endurance requirements: Some work has been done to define life-cycle testing parameters under simulated environmental conditions. However, for environmental test conditions, reliance appears to be on existing generic automotive or electronics testing requirements, which will require further modification for battery applications.

Environmental durability test requirements (e.g., temperature, humidity, vibration, etc.) could also be better defined, as current practices are to adapt existing automotive electronics requirements to the battery and battery management system on a case-by-case basis.

SAE is developing J1798, Recommended Practice for Performance Rating of Electric Vehicle Battery Modules, which provides for common test and verification methods to determine electric vehicle battery module performance.

In addition, UL has defined requirements and testing and certification services for batteries.

Gap: **Battery performance parameters and durability testing.** There is a need for further work on EV battery performance parameters and environmental durability test requirements.

Recommendation: Complete work on SAE J1798 and if possible consider harmonization with ISO 12405-2. ***Priority:*** Mid-term. ***Potential Developer:*** SAE, ISO.

4.1.1.4 Battery Storage, Packaging, Transport and Handling

Battery Storage

The following standards, code provisions and regulations relate to safety aspects of battery storage:

- IEC 60068, Environmental testing. Part 1: General and guidance, testing of the battery under different environmental conditions, which it expects to be exposed to during storage and operations.
- In terms of future work, IEC/TC 69 has plans to look at standards needed for battery swapping stations.
- ICC publishes the International Fire Code® (IFC®).
- NFPA 1, Fire Code, Chapter 52 covers stationary battery installations, which would come into play where batteries are used in a fixed energy storage facility.
- NFPA 13, Standard on Installation of Sprinkler Systems, addresses fire protection of storage occupancies. This document's technical committee is working on requirements for handling and storing EV batteries based on the results of the National Fire Protection Research Foundation report on lithium-ion batteries.
- NFPA 30A, Standard for Motor Fuel Dispensing Facilities and Repair Garages, covers fire protection requirements for fueling and service stations including service garages. This committee is also looking at requirements for safe handling of EV batteries at these locations.
- NFPA 70®, the National Electrical Code®, Article 480, Storage Batteries, 2011, covers the installation of electrical conductors, equipment, and raceways; signaling and communications conductors, equipment, and raceways; and optical fiber cables and raceways.
- SAE J2950, Recommended Practices (RP) for Transportation and Handling of Automotive-type Rechargeable Energy Storage Systems (RESS). This standard addresses identification, handling,

and shipping of un-installed RESSs to/from specified locations (types) required for the appropriate disposition of new and used items.

- OSHA 1910, storage batteries, where provisions shall be made for sufficient diffusion and ventilation of gases from storage batteries to prevent the accumulation of explosive mixtures.

Gap: **Safe storage of lithium-ion batteries.** At present, there are no standards addressing the safe storage of lithium-ion batteries specifically, whether at warehouses, repair garages, recovered vehicle storage lots, auto salvage yards, or battery exchange locations.

Recommendation*:* A standard on safe storage practices for EV batteries must be developed, addressing both new and waste batteries and the wide range of storage situations that may exist, including when the batteries are separated from their host vehicle. ***Priority:*** Near-term. ***Potential Developer:*** SAE, NFPA, ICC, IEC/TC 69.

Battery Packaging, Transport and Handling

So far, only limited standards work has been done in this area including:

- SAE J1797, Recommended Practice for Packaging of Electric Vehicle Battery Modules, published in 2008. This Recommended Practice provides for common battery designs through the description of dimensions, termination, retention, venting system, and other features required in an electric vehicle application.

- As noted above, SAE J2950, Recommended Practices (RP) for Transportation and Handling of Automotive-type Rechargeable Energy Storage Systems (RESS), is published.

- ISO/IEC PAS 16898.6 Electrically propelled road vehicles – dimension and designation of lithium-ion cells is in development.

At the end of 2010, the United Nations (UN) specifically classified lithium-ion batteries as part of its amendments to the model regulations on the transport of dangerous goods. Thus, transportation of *new* batteries is now covered by the International Air Transport Association (IATA), International Civil Aviation Organization (ICAO), International Maritime Organization (IMO), and local transportation regulations in countries of import/export, based on the appropriate UN number:

- 3090, Lithium Metal Batteries (including lithium alloy batteries);

- 3091, Lithium Metal Batteries Contained In Equipment (including lithium alloy batteries) or Lithium Metal Batteries Packed With Equipment (including lithium alloy batteries);

- 3480, Lithium-ion Batteries (including lithium-ion polymer batteries); and

- 3481, Lithium-ion Batteries Contained In Equipment (including lithium-ion polymer batteries) or Lithium-ion Batteries Packed With Equipment (including lithium-ion polymer batteries).

UN recommendations (Manual of Tests and Criteria, section 38) also cover packaging limitations to ensure proper containment against pressure and temperature changes, mechanical drops etc.

Gap: **Packaging and transport of waste batteries.** Current standards and regulations do not adequately cover transportation aspects of *waste* batteries (damaged, aged, sent for repair, end-of-life) in terms of packaging, loading limitations, combination with other dangerous goods on same transport, etc.

Recommendation*:* There is a need for a harmonized approach toward communication, labeling, packaging restrictions, and criteria for determining when a battery is waste. ***Priority:*** Near-term. ***Potential Developer:*** ISO/TC 22/SC21, SAE or UL.

Gap: **Packaging and transport of batteries to workshops or battery swapping stations.** Unloading a battery in a battery swapping station is extremely challenging with the original packaging used for dangerous goods transportation. There is a need for standards for intermediate packaging to cover transport to battery swapping stations.

Recommendation*:* Intermediate packaging is required between the import location of the battery and battery swapping stations and needs to be standardized around geometry, safety and matching to UN packaging requirements. ***Priority:*** Mid-term. ***Potential Developer:*** ISO/TC 22/SC21, SAE or UL.

4.1.1.5 Battery Recycling

No standards have been identified in relation to EV (li-ion) battery recycling.

In terms of regulations, lithium-ion battery recycling compliance requirements are limited to a few states in the U.S., including California, Oregon and Florida. The lack of harmonization and clear battery producer responsibility (in contrast to requirements in Europe for example) may potentially limit the battery recycling schemes in the U.S. Nevertheless, federal grants are given as an incentive to develop these recycling technologies and meet the demands of e-mobility in the U.S.

Gap: **Battery recycling.** Standards are needed in relation to EV (li-ion) battery recycling.

Recommendation*:* EV (li-ion) battery recycling standards are desirable to address the calculation method toward recycling efficiency and recovery rates based on an agreed unit (possibly weight) and/or life-cycle assessment tools, including energy recovery. ***Priority:*** Long-term. ***Potential Developer:*** SAE, IEC.

4.1.1.6 Battery Secondary Uses

SAE TEVVBC15, Secondary Battery Use Committee, is tasked with developing standards to address battery second life applications.

Gap: **Battery secondary uses.** There is a need for standards to address battery second life applications for grid storage and other uses.

Recommendation: Explore the development of standards for battery secondary uses, addressing such issues as safety and performance testing for intended applications, grid connection/communication interfaces, identification of parts/components that can be removed from the pack without destroying it, etc. ***Priority:*** Long-term. ***Potential Developer:*** SAE.

4.1.1.7 Crash Tests/Safety

The only federal motor vehicle safety standard that is unique to electric vehicles is FMVSS 305, Electric-Powered Vehicles: Electrolyte Spillage and Electrical Shock Protection. In 2010, FMVSS 305 was updated so as to align it more closely with the April 2005 version of SAE J1766, Recommended Practice for Electric and Hybrid Electric Vehicle Battery Systems Crash Integrity Testing. More recently, on July 29, 2011, the standard was again amended in response to petitions for reconsideration filed subsequent to the publication of the 2010 final rule. As amended, FMVSS 305 is intended to provide manufacturers greater flexibility, requiring them to design electrically-powered vehicles so that, in the event of a crash, the electrical energy storage, conversion, and traction systems are either electrically isolated from the vehicle's chassis or their voltage is below specified levels considered safe from electric shock hazards.

Since the physiological impacts of direct current (DC) are less than those of alternating current (AC), the standard specifies lower electrical isolation requirements for certain DC components (100 ohms/volt) than for AC components (500 ohms/volt). The recent rulemakings resulted in the introduction of new definitions, changes to existing definitions, changes to the energy storage/conversion device retention requirements, the introduction of a low voltage option for achieving electrical safety, and a requirement for monitoring of the isolation resistance of DC high voltage sources that comply with the 100 ohms/volt electrical isolation requirement. As amended, FMVSS 305 applies to passenger cars, multi-purpose vehicles (MPVs), trucks and buses that have a gross vehicle weight rating (GVWR) of 4,536 kg or less, that use electrical components with working voltages more than 60 volts direct current (VDC) or 30 volts alternating current (VAC), and whose speed attainable over a distance of 1.6 km on a paved level surface is more than 40 km/h. This differs from the previously-existing standard that similarly applied to passenger cars, MPVs, trucks and buses that have a GVWR of 4,536 kg or less but that was limited to vehicles that use more than 48 nominal volts of electricity as propulsion power and whose speed attainable in 1.6 km on a paved level surface is more than 40 km/h.

No gaps have been identified at this time with respect to this issue.

4.1.2 Vehicle Components

4.1.2.1 Internal High Voltage Cables, On-Board Wiring, Component Ratings and Charging Accessories

EV-specific standards related to this topic include:

- IEC TR 60783, Wiring and Connectors for Electric Road Vehicles, which applies to cabling and connectors used in battery electric road vehicles. These recommendations are not applicable to the low tension wiring (e.g. 12 V) for the auxiliary and signaling accessories, such as horn, lighting, signaling lamps, wipers, etc., nor do they apply to connections between cells of the traction battery. Rather, this document provides general rules for all external wiring and connectors which are used for interconnecting the traction components and sub-systems. The rules are applicable to the heavy current, the light current, and the signal harnesses. Currently, this publication has the status of a technical report, hence the "TR" designation.

- SAE J2894/1, Power Quality Requirements for Plug In Electric Vehicle Chargers. The intent of this published document is to develop a recommended practice for PEV chargers, whether on-board or off-board the vehicle, that will enable equipment manufacturers, vehicle manufacturers, electric utilities and others to make reasonable design decisions regarding power quality. The three main purposes are: 1) To identify those parameters of PEV battery charger that must be controlled in order to preserve the quality of the AC service; 2) To identify those characteristics of the AC service that may significantly impact the performance of the charger; and, 3) To identify values for power quality, susceptibility and power control parameters which are based on current U.S. and international standards. These values should be technically feasible and cost effective to implement into PEV battery chargers.

- SAE J2894/2, Power Quality Requirements for Plug In Electric Vehicle Chargers - Test Methods. A companion to SAE J2894/1, this standard is still in development but will describe the test methods for the parameters/requirements in this document. It will address automatic charger restarts after a sustained power outage, as well as the ability to ride through momentary outages.

- UL 62, Flexible Cords and Cables, which covers electric vehicle cable constructed as described in, and listed for use in accordance with, Article 400 of NFPA 70®, the National Electrical Code®. The cable is used to supply power, signal, and control to electric vehicles during the charging process. Electric vehicle cable consists of two or more insulated conductors, with or without grounding conductors, with an overall jacket.

- UL 458A, Power Converters/Inverters for Electric Land Vehicles, which covers power converters and power inverters intended for use in electric vehicles. This category covers fixed and stationary power converters, and accessories having a nominal rating of 600 V or less, direct or alternating current. This category also covers fixed, stationary and portable power inverters having a DC input and a 120 or 240 V AC output. These converters/inverters are intended for use within electric land vehicles where not directly exposed to outdoor conditions. This category also covers converters/inverters that are additionally intended to charge batteries.

- UL 2202, Electric Vehicle Charging System Equipment, which covers charging system equipment, either conductive or inductive, intended for use with electric vehicles. The equipment can be located on- or off-board the vehicle.

- UL 2733, Surface Vehicle On-Board Cable, which covers single-conductor or single, coaxial cable intended for the connection of components in an electric vehicle. The cable is rated 60, 75, 90 or 105°C (140, 167, 194 or 221°F), 300 or 600 V AC or DC, -30°C (-22°F), oil resistant, water resistant, and suitable for exposure to battery acid.

- UL 2734, Connectors for Use in On-board Electric Vehicle Charging Systems, which covers component connectors intended to interconnect both communication and power-circuit conductors rated up to 30 A and up to 600 V AC or DC within an on-board electric vehicle charging system.

General standards that may be applicable in the EV components environment include:

- IEC 61316, Industrial cable reels, which applies to cable reels with a rated operating voltage not exceeding 690 V AC/DC and 500 Hz with a rated current not exceeding 63A, primarily intended for industrial use, either indoors or outdoors, for use with accessories complying with IEC 60309-1.

- SAE J1654, High Voltage Primary Cable. This SAE Standard covers cable intended for use at a nominal system voltage up to 600 VDC or 600 VAC. It is intended for use in surface vehicle electrical systems.

- SAE J1673, High Voltage Automotive Wiring Assembly Design. This SAE Recommended Practice covers the design and application of primary on-board wiring distribution system harness to road vehicles. This document applies to any wiring systems which contains one or more circuits operating between 50V DC or AC RMS and 600 V DC or AC RMS excluding automotive ignition cable.

- SAE J1742, Connections for High Voltage On-Board Road Vehicle Electrical Wiring Harnesses - Test Methods and General Performance Requirements. Procedures included within this specification are intended to cover performance testing at all phases of development, production, and field analysis of electrical terminals, connectors, and components that constitute the electrical connection systems in high power road vehicle applications that operate at either 20 V to 600 volts regardless of the current applied, or any current greater than or equal to 80 A regardless of the voltage applied. These procedures are applicable only to terminals used for In-Line, Header, and Device Connectors and for cable sizes up to 120 mm2 (4/0).

- UL 1004-1, Traction Motors, which covers motors intended as the prime mover and installed in or on vehicles for highway use, such as passenger automobiles, buses, trucks, vans, bicycles, motorcycles and the like. These motors have been investigated for construction and operation at rated output. They have additionally been investigated for the severity and profile of shock and vibration likely to be encountered by motors mounted in road vehicles.

- USCAR-37, High Voltage Connector Performance Supplement to SAE/USCAR-2. Procedures included within this specification supplement are, when used in conjunction with SAE/USCAR 2, intended to cover performance testing at all phases of development, production, and field analysis of electrical terminals, connectors, and components that constitute the electrical connection systems in high voltage (60~600V) road vehicle applications. These procedures are applicable to terminals used for In-Line, Header, and Device Connector systems with and without Shorting Bars.

In Europe and in other countries around the world, electric vehicles and on-board components are subject to review through both European and UN regulations. These regulations include European Regulations 2007/46/EC or 2002/24/EC and the UNECE Regulations R100. UNECE R100 is the UN Regulation which tests specific requirements for the construction, functional safety and hydrogen emissions of battery electric vehicles. UNECE R100 is required by many countries before an electric vehicle can be road registered, and is also required before European Community Whole Vehicle Type Approval (ECWVTA) can be issued. Safety Regulations and requirements within UNECE R100 include: vehicle constructional requirements (e.g., prevention of gas accumulation and correctly rated circuit breakers); protection against electric shock through the assessment of covers and enclosures associated with high voltage components; assessment of access to high voltage components according to protection degrees, etc.

In the U.S., FMVSS 305, Electric-powered vehicles: electrolyte spillage and electrical shock protection, is similar to R100 in Europe. In addition, all motor vehicles and items of motor vehicle equipment are covered by the Motor Vehicles Safety Act in the U.S., meaning they are covered by NHTSA's recall and remedy provisions in the event there exists a safety-related defect.

No gaps have been identified at this time with respect to this issue.

4.1.2.2 Vehicle Diagnostics – Emissions

In 1993, pursuant to Clean Air Act, the U.S. Environmental Protection Agency (EPA) published a final rulemaking requiring manufacturers of light-duty vehicles and light-duty trucks to install on-board diagnostic (OBD) systems on such vehicles beginning with the 1994 model year. The regulations promulgated in that final rule require manufacturers to install OBD systems which monitor emission control components for any malfunction or deterioration causing exceedance of certain emission thresholds, and which alert the vehicle operator to the need for repair. That rulemaking also requires that, when a malfunction occurs, diagnostic information must be stored in the vehicle's computer to assist the technician in diagnosis and repair.

Since the inception of the program, vehicle manufacturers have been allowed to satisfy federal OBD requirements by installing OBD systems satisfying the OBD II requirements promulgated by the California Air Resources Board (CARB).

Because hybrid electric vehicles and plug-in hybrid electric vehicles are equipped with conventional internal combustion or diesel engines, they comply with CARB and EPA OBD requirements. In some cases, there are special OBD requirements that are specific to these hybrid and plug-in hybrid electric vehicles.

CARB's OBD II rules can be found at:

- Title 13, California Code Regulations, Section 1968.2, Malfunction and Diagnostic System Requirements for 2004 and Subsequent Model-Year Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles and Engines (OBD II); and

- Title 13, California Code of Regulations, Section 1968.5, Enforcement of Malfunction and Diagnostic System Requirements for 2004 and Subsequent Model-Year Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles and Engines.

For copies, see http://www.arb.ca.gov/msprog/obdprog/obdregs.htm.

Note: In December 2011, CARB proposed amendments to its OBD II regulation which, among other things, would clarify how certain requirements are to be applied to hybrid and plug-in hybrid electric vehicles. The proposed amendments were adopted by the Board at a hearing held Jan. 26-27, 2012. A copy of the regulation as amended is available at:

http://www.arb.ca.gov/msprog/levprog/leviii/leviii.htm.

No gaps have been identified at this time with respect to this issue.

4.1.2.3 Audible Warning Systems

Numerous activities are underway to address the concern that electric and some hybrid electric vehicles may not be audibly detectable by the blind. These include NHTSA rulemaking (stemming from the Pedestrian Safety Enhancement Act of 2010), Japanese and UNECE guidelines requiring EVs and HEVs to generate a pedestrian alert sound, SAE and ISO technology neutral procedures for measuring vehicle sound at low speeds, and development of a Global Technical Regulation (GTR).

In accordance with the Pedestrian Safety Enhancement Act of 2010, electric and hybrid electric vehicles must emit an alert sound that allows blind and other pedestrians to reasonably detect a nearby electric or hybrid vehicle operating below a certain cross-over speed. The alert sound must be in compliance with a new safety standard that NHTSA is required to create in accordance with the law. NHTSA has 36 months to finalize the new standard. Under the law, the new standard will be phased-in over a 36 month period following publication of the final rule.

The NHTSA rulemaking is expected to incorporate portions of SAE J2889-1 (Countermeasure Performance Evaluation & Test Procedure) which was published in September 2011. At the request of NHTSA, SAE plans to continue to refine the standard to include development of metrics and measurement procedures for changes to pitch and volume for innate and synthetic vehicle sounds. SAE's goal is to have these refinements incorporated into a revised standard prior to the publication of NHTSA's proposal in mid-2012. Long-term, SAE is prepared to address pending technologies such as radio frequency-based Dedicated Short-Range Communications (DSRC) as well as other new and developing technologies that may contribute to addressing the concern. It should be noted that the SAE work product is the basis for ISO/NP 16254 (an identical sound measurement standard).

Outside the U.S., electric and hybrid electric vehicles are being designed to comply with voluntary guidelines. The Japanese Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has voluntary guidelines which require that EVs and HEVs generate a pedestrian alert sound whenever the vehicle is moving forward at any speed less than 20 km/h and when the vehicle is operating in reverse. MLIT guidelines do not require vehicles to produce an alert sound when the vehicle is operating, but stopped, such as at a traffic light. The manufacturer is allowed to equip the vehicles with a switch to deactivate the alert sound temporarily. In Europe, the UNECE has adopted guidelines covering alert sounds for EVs and HEVs that are closely based on the Japanese guidelines. The guidelines will be published as an annex to the UNECE Consolidated Resolution on the Construction of Vehicles (R.E.3).

To address harmonization, the UNECE WP.29 Working Party on Noise (GRB) has established an informal working group (the Quiet Road Transport Vehicles (QRTV) Working Group) to carry out activities that are considered essential to determine the viability of "quiet vehicle" audible acoustic signaling techniques and the potential need for their global harmonization. The United States, represented by NHTSA, participates in this activity, and in June of 2011, the U.S. representative proposed that a GTR be developed. That work is currently ongoing and will likely continue in parallel with the NHTSA rulemaking activity.

Partial Gap: **Audible warning systems.** Creation of the NHTSA safety standard and compliance with it will effectively close any gap with respect to audible warning systems for electric vehicles sold in the U.S. market. Ongoing standards work in SAE and ISO, and in WP.29 with respect to the development of a Global Technical Regulation (GTR) would provide a means for international harmonization around this issue.

Recommendation*:* Continue work on safety standards to address EV sound emission and measurement. ***Priority:*** Near-term. ***Potential Developer:*** SAE, ISO, NHTSA, WP.29.

4.1.3 Vehicle User Interface

4.1.3.1 Graphical Symbols

There are several international standards and guidelines relating to graphical symbols and how to develop them. These are general in nature and not specific to electric vehicles, but may be utilized by standards development groups to develop a set of electric vehicle graphical symbols standards. There are also some publications that relate specifically to markings on electrical equipment and instrumentation for electric vehicles. These include:

- IEC 60445, Basic and safety principles for man-machine interface, marking and identification - Identification of equipment terminals, conductor terminations and conductors, published in 2006, which contains rules for markings of electrical equipment including colors for conductors.

- IEC TR 60784, Instrumentation for electric road vehicles, published in 1984, provides high level guidance on information that should be provided to the driver regarding operating and other states of an electric vehicle battery.

SAE is developing J2936 on Vehicle Battery Labeling Guidelines. This will cover any electrical storage device at all levels of sub-component, component, subsystem and system level architectures describing content, placement and durability requirements of labels.

In terms of Federal Motor Vehicle Safety Standards and Regulations, there is:

- NHTSA FMVSS 101, Controls and Displays, most recently published in 2008, which provides performance requirements for the location, identification, color, and illumination of motor vehicle controls, telltales and indicators. It is not electric vehicle specific.

Gap: **Graphical symbols for electric vehicles.** Standards for graphical symbols for electric vehicles are needed to identify important terminals and parts visible under the hood, as well as to communicate information to the driver which can be understood regardless of the driver's language.

Recommendation*:* Complete work to develop SAE J2936. Develop EV graphical symbols standards for parts under the hood and to communicate information to the driver. ***Priority:*** Near-term. ***Potential Developer:*** SAE, ISO, IEC.

4.1.3.2 Telematics – Driver Distraction

The following are relevant with respect to conventional vehicles:

1. Auto Alliance Driver Focus Telematics Guidelines. This guideline provides 24 design principles for telematics systems human-machine interaction design to minimize the potential for driver distraction. Each design principle has a rationale, design criteria and evaluation procedure to help designers implement the requirements. Four categories of design principles for navigation, telephone call management, electronic messaging and interactive services are currently addressed in this document.

2. NHTSA Driver Distraction Guidelines. On February 24, 2012, NHTSA issued proposed nonbinding, voluntary guidelines to promote safety by discouraging the introduction of excessively distracting devices in vehicles. These guidelines cover original equipment in vehicle device secondary tasks (i.e., communications, entertainment, information gathering, and navigation tasks not required for driving) performed by the driver through visual-manual means. See: https://www.federalregister.gov/articles/2012/02/24/2012-4017/visual-manual-nhtsa-driver-distraction-guidelines-for-in-vehicle-electronic-devices (comments due April 24, 2012).

3. NHTSA – FMVSS 101. This standard specifies performance requirements for location, identification, color, and illumination of motor vehicle controls, telltales and indicators. The purpose of this standard is to ensure the ready access, visibility and recognition of motor vehicle controls and to facilitate the proper selection of controls under daylight and night time

conditions, in order to reduce the safety hazards caused by the diversion of the driver's attention from the driving task and by mistakes in selecting controls.

No gaps have been identified at this time; however, if there are any special consideration vis a vis driver distraction in EVs, those can be communicated to NHTSA in conjunction with the development of the proposed guidelines.

4.1.3.3 Fuel Efficiency, Emissions and Labeling

On July 6, 2011, a new federal regulation titled, "Revisions and Additions to Motor Vehicle Fuel Economy Label" was issued (Federal Register: Vol. 76, No. 129, pages 39478 – 39587, [Docket ID; EPA–HQ–OAR–2009–0865; FRL–9315–1; NHTSA–2010–0087]). This was a joint rule issued by both the Environmental Protection Agency (EPA) and NHTSA. The regulation establishes new requirements (40 CFR Parts 85, 86, and 600, and 49 CFR Part 575) for the fuel economy and environmental label that will be posted on the window sticker of all new automobiles sold in the U.S. The rule is effective September 6, 2011 and the labeling requirements apply for model year 2013 and later.

This joint final rule by EPA and NHTSA represents the most significant overhaul of the federal government's fuel economy label or "sticker" since its inception over 30 years ago. The redesigned label will provide new information to American consumers about the fuel economy and consumption, fuel costs, and environmental impacts associated with purchasing new vehicles. The new rule will result in the development of new labels for certain advanced technology vehicles, which are poised to enter the U.S. market, in particular plug-in hybrid electric vehicles and electric vehicles. This rule uses miles per gallon gasoline equivalent for all fuel and advanced technology vehicles available in the U.S. market including plug-in hybrids, electric vehicles, flexible-fuel vehicles, hydrogen fuel cell vehicles, and natural gas vehicles.

The following four SAE standards are referenced in the regulation:

- SAE J1634, Electric Vehicle Energy Consumption and Range Test Procedure;
- SAE J1711, Recommended Practice for Measuring the Exhaust Emissions and Fuel Economy of Hybrid-Electric Vehicles, Including Plug-in Hybrid Vehicles;
- SAE J2572, Recommended Practice for Measuring Fuel Consumption and Range of Fuel Cell and Hybrid Fuel Cell Vehicles Fuelled by Compressed Gaseous Hydrogen; and
- SAE J2841, Utility Factor Definitions for Plug-In Hybrid Electric Vehicles Using Travel Survey Data.

The redesigned label provides expanded information to American consumers about new vehicle fuel economy and fuel consumption, greenhouse gas and smog-forming emissions, and projected fuel costs and savings, and also includes a smartphone interactive code that permits direct access to additional web resources. Additional information for advanced technology vehicles includes driving range and battery charge time.

No gaps have been identified at this time with respect to this issue.

4.2 Infrastructure Domain

4.2.1 Charging Systems

4.2.1.1 Wireless Charging

SAE International is currently in the process of developing a standard, SAE J2954, Wireless Charging of Electric and Plug-in Hybrid Vehicles. The standard will cover all equipment aspects from grid to vehicle charging with a key focus on interoperability between the primary (charging mat) and secondary (pick-up located on vehicle) when the two aforementioned components are manufactured by two different suppliers. The SAE taskforce is reviewing the state of the art of wireless charging (e.g., inductive, magnetic resonance) and compiling an interoperability study. An initial release of the document, which will be initially published as a guideline, is due out sometime in 2012. The document will be a working document, as further research for this technology is currently underway, and it will become a standard for publication in 2014/2015.

UL is developing UL2750 to cover safety aspects of wireless charging in parallel with the design standard SAE J2954 under development by SAE.

Gap: **Wireless charging.** SAE J2954 on wireless charging design and UL 2750 on wireless charging safety are still in development.

Recommendation: Complete work on SAE J2954 and UL 2750. ***Priority:*** Near-term. ***Potential Developer:*** SAE, UL.

4.2.1.2 Battery Swapping

To date, standards development activities with regards to battery swapping have been relatively limited. In June 2011 the Chinese released for public comments nine standards that deal with battery swapping including: terminology, general requirements, testing specifications and construction codes.

The CEN/CENELEC focus group report on European Electro-Mobility from July 2011 specified the need for international battery swapping standards addressing safety, energy needs, exchangeability, ready access, data and communication framework. Recently, IEC/TC 69 has indicated that it will take up this subject using the Chinese standards as the initial input to that work. This is now in the work programme of TC 69.

If swapping out a battery also involves the separation of a liquid thermal system (vs. air-cooled battery), this will need to be carefully assessed.

Gap: **Battery swapping – safety.** Currently, there is a need to define minimum requirements for the safe operation of battery swapping stations, as deployment of battery swapping systems is currently underway in several countries around the world.

Recommendation: Define minimum requirements for the safe operation of battery swapping stations. ***Priority:*** Near-term. ***Potential Developer:*** IEC/TC 69.

Gap: **Battery swapping – interoperability.** Standards are needed to help facilitate the penetration of battery swapping in the market. Issues to be addressed related to removable batteries include electrical interfaces, cooling integration, data transfer integration, and common mechanical and dimensional interfaces.

Recommendation: Define interoperability standards related to battery swapping. ***Priority:*** Near-term. ***Potential Developer:*** IEC/TC 69.

4.2.1.3 Electric Vehicle Supply Equipment (EVSE)

Power Quality

SAE International is in the process of publishing SAE J2894, Power Quality Requirements for Plug-in Electric Vehicle Chargers. SAE J2894/1 contains the requirements while SAE J2894/2 contains the test procedures for those requirements. The increasing number of plug-in electric vehicle chargers has caused concern over their combined effects on the power quality and reliability of electric utility grids.

- SAE J2894/1 contains both requirements for the power quality of the vehicle chargers and the characteristics of the electric grid. It includes power quality requirements on the power factor, AC to DC conversion efficiency, harmonic current distortion, and inrush current. This document also describes what the normal characteristics of the electric grid are and the characteristics of some events that could occur on the electric grid. These events include voltage swell, surge, sag, and distortion, as well as momentary outage and frequency variations.

- SAE J2894 notes that generators that would be used in a home do not have the same power quality as the electric grid and that user experiences could be affected by vehicle chargers that do not work properly due to the use of these generators. J2847/1 and J2836/1™ are referenced in J2894/1 to link the communications and power quality documents. J2894 discusses what is known as “cold load pickup,” which is when power is restored after a loss of utility power with many devices still connected and on that attempt to restart at the same time. All of these devices, including vehicle chargers then draw their respective inrush currents, leading to a possible current of up to five times normal load. A restart load rate is described in order to keep this initial load to a manageable level.

Partial Gap: **Power quality.** SAE J2894/1 was published in December 2011. SAE J2894, Part 2, is still in development.

Recommendation: Complete work on SAE J2894, Part 2. ***Priority:*** Near-term. ***Potential Developer:*** SAE.

EVSE Charging Levels/Modes

SAE J1772™, the Recommended Practice for Electric Vehicle and Plug In Hybrid Electric Vehicle Conductive Charge Coupler, organizes the potential charging options into different "levels." IEC also provides categories for charging "modes" in IEC 61851. These standards identify the voltage, number of phases, maximum current, and required branch circuit protection for each level or mode. These parameters, coupled with the battery charge parameters, dictate the length of time the vehicle will take to charge. To determine the charge time, consider that the higher the level or mode, the higher the voltage and current, and therefore the quicker the charge. Battery properties and vehicle characteristics must also be taken into account in order to determine the charging time.

While the SAE and IEC standards for conductive charging dictate different power parameters for each level or mode, the operational parameters of the vehicle and EVSE generally remain the same from level to level or mode to mode. In future applications, very high power and/or high voltages may require additional safeguards to address these special applications. Specifications such as vehicle state voltages and control pilot circuit parameters are consistent for each level within SAE and each mode within IEC standards. This allows EV drivers to utilize any of the AC levels/modes of charging available, provided that the connector meets the SAE J1772™ or the car is compatible with one of the IEC connector types available on that station.

EVSE manufactured for the U.S. market, and vehicles sold and operated in the U.S., generally follow the SAE J1772™ standard. EVSE manufactured for the European market, and vehicles sold and operated in Europe, generally follow the IEC 61851 standards.

Figure 6 describes the SAE charging configurations and ratings terminology. AC Levels 1 and 2 are defined in the published version of SAE J1772™. The charging parameters for DC L1, DC L2, and DC L3 are being finalized for a future release of SAE J1772™. There was an AC L3 in earlier versions of J1772™ but it is now listed as to be determined (TBD).

▸ AC L1: 120V AC single phase - Configuration current 12, 16 amp - Configuration power 1.44, 1.92kw	▸ DC L1:$^{\Delta}$ 200 – 500V DC - Rated Current ≤ 80 amp - Rated Power ≤ 40kw
▸ AC L2: 240V AC single phase - Rated Current ≤ 80 amp - Rated Power ≤ 19.2kw	▸ DC L2:$^{\Delta}$ 200 – 500V DC - Rated Current ≤ 200 amp - Rated Power ≤ 100kw
▸ AC L3:TBD - AC single or 3ϕ ?	▸ DC L3: TBD - 200 – 600V DC ? - Rated Current ≤ 400 amp? - Rated Power ≤ 240kw?

Figure 6: SAE Charging Configurations and Ratings Terminology (Used with Permission of SAE International)

Voltages are nominal configuration operating voltages, not coupler rating.
Rated power is at nominal configuration operating voltage and coupler rated current.
Δ Values Not Finalized

SAE J1772™ has the following information:

> It is recommended that residential EVSEs input current rating be limited to 32 amp (40 amp branch breaker) unless the EVSE is part of a home energy management system. Residential EVSEs with input current ratings of greater than 32 amp without home energy management may require substantial infrastructure investment by the resident owner, utility, or both.

As noted, SAE J1772™ is used in the U.S. and is also contained in the IEC 61851 series of standards. IEC 61851-1, 22, 23 & 24 includes other connectors that are used in Europe and other areas. The IEC 61851 series addresses safety aspects and EVSE and the IEC 62196 series addresses the connectors. All of these aspects are covered in SAE J1772™.

Europe has variations for the infrastructure since they have Case A, B & C, described in IEC 61851-1 and IEC 62196-1. Case A is when the cable is fixed to the vehicle. Case B is when the cable has a connector on both ends. Case C is when the cable is fixed to the EVSE. They also have Modes 1, 2, 3 & 4. The Modes and requirements are described in IEC 61851-1 (Ed. 2 (2010 edition) as follows (below text is directly excerpted from the standard):

- **Mode 1 charging:** connection of the EV to the a.c. supply network (mains) utilizing standardized socket-outlets not exceeding 16 A and not exceeding 250 V a.c. single-phase or 480 V a.c. three-phase, at the supply side, and utilizing the power and protective earth conductors.

  NOTE 2 In the following countries, mode 1 charging is prohibited by national codes: US.

  NOTE 3 The use of an in-cable RCD can be used to add supplementary protection for connection to existing a.c. supply networks.

  NOTE 4 Some countries may allow the use of an RCD of type AC for mode 1 vehicles connected to existing domestic installations: JP, SE.

- **Mode 2 charging:** connection of the EV to the a.c. supply network (mains) not exceeding 32 A and not exceeding 250 V a.c. single-phase or 480 V a.c. three-phase utilizing standardized single-phase or three-phase socket-outlets, and utilizing the power and protective earth conductors together with a control pilot function and system of personnel protection against electric shock (RCD) between the EV and the plug or as a part of the in-cable control box. The inline control box shall be located within 0,3 m of the plug or the EVSE or in the plug.

  NOTE 5 In the USA, a device which measures leakage current over a range of frequencies and trips at predefined levels of leakage current, based upon the frequency is required.

  NOTE 6 In the following countries, according to national codes, additional requirements are necessary to allow cord and plug connection to a.c. supply networks greater than 20 A, 125 V a.c.: US.

  NOTE 7 For mode 2, portable RCD as defined in IEC 61540 and IEC 62335 is applicable.

NOTE 8 In Germany the inline control box (EVSE) shall be in the plug or located within 2,0 m of the plug.

- **Mode 3 charging:** connection of the EV to the a.c. supply network (mains) utilizing dedicated EVSE where the control pilot function extends to control equipment in the EVSE, permanently connected to the a.c. supply network (mains).
- **Mode 4 charging:** connection of the EV to the a.c. supply network (mains) utilizing an offboard charger where the control pilot function extends to equipment permanently connected to the a.c. supply.

It is recognized that vehicle manufacturers may have to design vehicles with regional kits that will allow the appropriate connector and voltage interface for the region of use.

Partial Gap: **EVSE charging levels.** The levels for DC charging within SAE J1772™ have yet to be finalized.

Recommendation*:* Complete work to establish DC charging levels within SAE J1772™. ***Priority:*** Near-term. ***Potential Developer:*** SAE.

Off-Board Chargers and Supply Equipment

Today, off-board chargers are covered by UL 2202, the Standard for Electric Vehicle (EV) Charging Equipment. Off-board charging stations and portable EV cord sets are covered by UL 2594, the Standard for Electric Vehicle Supply Equipment.

Currently, there is a harmonization effort underway to use UL 2594 as the basis for the North American Standard. This harmonization effort is expected to be completed in 2012.

The harmonization of UL 2594 with Canada and Mexico will cover the safety requirements for off-board charging stations and portable EV cord sets, with respect to risk of fire, shock and injury to persons. Once the harmonization of UL 2594 is complete, there should be no gaps in standardization for this equipment in North America. The priority for this work would be considered high as it is already in progress.

Partial Gap: **Off-board charging station and portable EV cord set safety within North America.** Harmonization of equipment safety standards within North America is underway based on the UL 2594 standard.

Recommendation*:* Finish efforts to harmonize standards addressing off-board charging station and portable EV cord set safety within North America. ***Priority:*** Near-term. ***Potential Developer:*** UL, CSA, ANCE (Mexico), NEMA.

There is currently no harmonization effort in progress for UL 2202. However, the harmonization of the safety requirements for off-board chargers would be needed to address safety concerns in the same manner as harmonization of UL 2594 as stated above.

Partial Gap: **Off-board charger safety within North America.** Harmonization of equipment safety standards within North America is needed.

Recommendation: There appears to be a need to harmonize the safety requirements for off-board chargers with the U.S., Canada, and Mexico. ***Priority:*** Mid-term. ***Potential Developer:*** UL, CSA, ANCE (Mexico), NEMA.

The IEC 61851 series of standards also address safety of off-board chargers, off-board charging stations, and portable EV cord sets.

- IEC 61851-1, Electric Vehicle Conductive Charging Systems, Part 1: General Requirements; and
- IEC 61851-22, Electric Vehicle Conductive Charging Systems, Part 22: AC Electric Vehicle Charging Stations.

The IEC 61851 standards are similar in many respects to the North American standards. However, due to the differences in the protection system requirements, the standards create a gap in how to apply one protection system to meet both documents. In addition, gaps such as the acceptance of components and the IEC standards needed to evaluate these components, and the use of IEC ingress protection (IP) ratings of the enclosure.

Harmonization between the North American safety standards and the IEC 61851 standards is being driven through IEC work and U.S. participation in the appropriate IEC committees. However, no formal program or specific project has been initiated to actually harmonize these standards. Up to this point, the effort has been focused on introducing specific aspects into either the North American standards, or the IEC standards, as opportunity allows.

Partial Gap: **Off-board charger, off-board charging station and portable EV cord set safety globally.** There are some differences between the IEC 61851 series of standards and the North American standards. While not a gap per se with respect to the U.S. market, the use of infrastructure equipment and the means to mitigate risks would prove beneficial to manufacturers if harmonization was completed.

Recommendation: Work to harmonize the IEC 61851 series standards and the North American standards. ***Priority:*** Mid-term. ***Potential Developer:*** UL, IEC.

Conformance Programs

Various conformance programs exist, with each third party testing organization having a program in place. Article 625 of the National Electrical Code® requires off-board chargers, off-board charging stations, and portable EV cord sets to be listed. So, conformance programs are essential to listing the product. Although all conformance programs have their own specific parts, for off-board charging stations and portable EV cord sets, all North American conformance programs will be based on the North American standards as shown above, and all will eventually be using the new harmonized standard (based on UL 2594) once it is published.

EV Couplers: Safety and Harmonization Efforts

Today, UL 2251, Standard for Plugs, Receptacles and Couplers for Electric Vehicles, exists to cover for EV couplers. A harmonization process is underway to use the UL 2251 standard as a basis for a North American standard. The harmonized standard is expected to be published in early 2012. The harmonized standard will cover the safety requirements for vehicle connectors and vehicle inlets, with respect to the risk of fire, shock, and injury to persons for both AC and DC rated EV couplers. Once this harmonization process is complete, there should be no gaps in standardization for EV coupler safety in North America, including the U.S., Canada and Mexico. The priority for this work would be considered high as it is currently in process.

Partial Gap: **EV coupler safety within North America.** Harmonization of EV coupler safety standards within North America is underway based on the UL 2251 standard.

Recommendation*:* Finish efforts to harmonize standards addressing EV coupler safety within North America. ***Priority:*** Near-term. ***Potential Developer:*** UL, CSA, ANCE (Mexico), NEMA.

The IEC 62196 series of standards also address safety of the EV coupler:

- IEC 62196-1, Plugs, Socket-Outlets, Vehicle Connectors and Vehicle Inlets – Conductive Charging of Electric Vehicles – Part 1: General Requirements; and
- IEC 62196-2, Plugs, Socket-Outlets, Vehicle Connectors and Vehicle Inlets – Conductive Charging of Electric Vehicles – Part 2: Dimensional Compatibility and Interchangeability Requirements for AC Pin and Contact-Tube Accessories.

The IEC 62196 standards are similar in many respects to the North American standards. They go further in that the Part 2 includes the specific vehicle inlet and connector interface (configuration) drawings, ratings information and other details to allow interchangeable devices to be made by many manufacturers. They also insure that other types of vehicle couplers used in other countries will not mismatch with the devices recommended by U.S. manufacturers.

There are some differences between IEC 62196 series standards and the existing North American standards. These gaps include some construction issues such as acceptance of components and the IEC standards used to certify and test these components, the mandatory use of latching means, and the use of IEC ingress protection (IP) ratings. They include testing differences such as additional test methods for enclosure strength testing, environmental testing on enclosures (IP ratings), and impact testing on inlets.

Harmonization between the North American coupler safety standards and the IEC 62196 standards is being driven through IEC work and U.S. participation in the appropriate IEC committees. However, no formal program or specific project has been initiated to actually harmonize these standards. Up to this point, the effort has been focused on introducing specific aspects into either the North American standards, or the IEC standards, as opportunity allows. The fact that harmonized standards do not exist globally creates the situation where different connectors are being used in different geographic areas. In some cases, these differences cannot be eliminated because of differences in the infrastructure. In other cases, harmonization would be a good thing, but at the moment would appear to be more of a mid-term goal.

Partial Gap: **EV coupler safety globally.** There are some differences between IEC 62196 series standards and the North American EV coupler safety standards. While not a gap per se with respect to the U.S. market, global harmonization would help to reduce costs for vehicle manufacturers.

Recommendation*:* Work to harmonize the IEC 62196 series standards and the North American EV coupler safety standards. ***Priority:*** Mid-term. ***Potential Developer:*** UL, IEC.

In addition to IEC 62196 parts 1 and 2, a new Part 3, Dimensional Compatibility and Interchangeability Requirements for Dedicated DC and combined AC/DC Pin and Contact-Tube Vehicle Couplers, is being developed. It will be similar to Part 2 in that it will standardize and contain all of the details to build either DC or AC/DC vehicle couplers.

Based upon the continuing development of EV couplers and EV charging stations, these standards will likely go through revision phase beginning next year.

Conformance Programs

Section 1962.2, Title 13, of the California Code of Regulations, requires 2006 and later model year vehicles to be equipped with a conductive charger inlet port which meets all the specifications contained in SAE J1772™. This is also a requirement in states that have adopted the California Air Resources Board (CARB) zero emission vehicle (ZEV) requirements pursuant to section 177 of the federal Clean Air Act (42. U.S.C. Sec. 7507) ("S.177 states"). In March 2012, section 1962.2, Title 13, was amended so as to permit a manufacturer to apply for approval to use an alternative to the AC inlet specified in SAE J1772™ provided that the following conditions are met: (a) each vehicle is supplied with a rigid adaptor that would enable the vehicle to meet all of the remaining system and on-board charger requirements described in J1772, and (b) the rigid adaptor and alternative inlet must be tested and approved by a Nationally Recognized Testing Laboratory.

Various other conformance programs exist, with each third party testing organization having a program in place. Article 625 of the National Electrical Code® requires EV couplers, EVSE and EV charging systems to be listed. So, conformance programs are essential to listing the product. Although all conformance programs have their own specific parts, all North American conformance programs will be based on the North American standards as shown above, and all will eventually be using the new harmonized standard (based on UL 2251) once it is published.

EV Couplers: Interoperability and Harmonization Efforts

SAE J1772™ covers the interface, design, geometry, communication protocol, and pilot controls for electric vehicle infrastructure as it is communicated through the EV connector. Conforming to this SAE document means that any vehicle supplied with an SAE J1772™ inlet on the vehicle can pull up to any SAE J1772™ infrastructure type device (which would be provided with an SAE J1772™ style connector) and be able to charge the vehicle. This type of harmonization is essential for interoperability.

To enhance convenience, offer a more robust consumer experience, and provide for the "plugging in" to DC charging stations in both public and commercial settings, SAE International is revising the SAE J1772™ standard to include DC fast charging capabilities. The DC connector configuration is under development during this revision cycle.

Outside of the U.S. market, EV couplers are diverse:

- For AC charging, different connectors exist in Europe and China, while Japan uses the SAE J1772™ EV coupler.
- For DC charging, Europe and China are developing their own EV coupler, while Japan is using the CHAdeMO configuration.

This diversity in the EV coupler has caused the need for different products to be manufactured for different countries as well as modifications to vehicles that will be shipped around the world.

Harmonization of EV couplers on a global scale would prove beneficial, but is difficult. In fact, due to differences in electrical systems, each country's own national rules and regulations, and so forth, in some cases, harmonization could prove impossible. EV coupler configurations are already well established in some locations, and the need to change them does not seem to be a high priority. Also, with the advent of DC quick charging, the need to harmonize AC connectors has become less of an issue. Once sufficient infrastructure is in place, it may prove difficult to switch connector types, so the harmonization effort for DC connectors would be considered a near-term goal.

Partial Gap: **EV coupler interoperability globally.** Different coupler configurations are used in different parts of the world. While not a gap per se with respect to the U.S. market, global harmonization would help to reduce costs for vehicle manufacturers.

Recommendation*:* Work to harmonize EV coupler configurations in particular with respect to DC charging. ***Priority:*** Near-term. ***Potential Developer:*** SAE, IEC, CHAdeMO.

Conformance Programs

As noted above, compliance requirements with respect to SAE J1772™ and the charger inlet port are specified in California's ZEV requirements which also apply to S.177 states. As such, it is currently the de facto EV charge coupler standard in the U.S.

SAE is developing J2953, Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE), which establishes the interoperability requirements and specifications for the communication systems between PEVs and EVSE for multiple suppliers.

There is also a verification program currently being developed by Underwriters Laboratories, Inc. that may be used to prove that infrastructure equipment, which includes the vehicle connector, will be compatible with all vehicles that meet the SAE J1772™ protocol for AC charging. A similar program is under development in Japan for the CHAdeMO EV coupler.

Gap: **Conformance programs for EV coupler interoperability within the U.S. market.** A program(s) is needed for the U.S. market to verify compatibility between the EV coupler, the infrastructure and the vehicle.

Recommendation*:* Complete work on SAE J2953. Establish a program(s) to verify interoperability between infrastructure equipment, including the vehicle connector, and all vehicles that follow the SAE J1772™ protocol. ***Priority:*** Near-term. ***Potential Developer:*** SAE, UL.

4.2.1.4 Electromagnetic Compatibility (EMC)

SAE J551-1, Performance Levels and Methods of Measurement of Electromagnetic Compatibility of Vehicles, Boats (up to 15 m), and Machines (16.6 Hz to 18 GHz), covers the measurement of radio frequency (rf) radiated emissions and immunity. Each part details the requirements for a specific type of electromagnetic compatibility (EMC) test and the applicable frequency range of the test method. The methods are applicable to a vehicle . . . powered by an internal combustion engine or battery powered electric motor. As all of the vehicle tests are evaluating the complete vehicle, the source of power is immaterial. SAE J551-1 adopts by reference IEC CISPR 12 and CISPR 25 which apply to all vehicles and other equipment. CISPR 25 is in the process of being updated to adapt the test methods to safely test high voltage components in the vehicle. The SAE J1113 series covers EMC testing of vehicle components.

Presently, the only EV-specific standard for EMC is SAE J551-5-2012, Performance Levels and Methods of Measurement of Magnetic and Electric Field Strength from Electric Vehicles, 9 kHz to 30 MHz, which covers conducted emission measurements that are applicable only to battery-charging systems which utilize a switching frequency above 9 KHz, are mounted on the vehicle, and whose power is transferred by metallic conductors. Conducted emission requirements apply only during charging of the batteries from AC power lines. Conducted and radiated emissions measurements of battery-charging systems that use an induction power coupling device are not covered; radiated emissions for an electric vehicle in operation at a constant speed are covered.

There is a current international agreement between IEC and ISO regarding EMC as follows: EMC immunity issues relating to vehicles (internal combustion, battery, fuel cell or hybrid powered) while not connected to the power grid are the responsibility of ISO/TC 22 and rf emissions are the responsibility of IEC CISPR/D. EMC issues relating to vehicles while connected to the power grid for charging are the responsibility of IEC/TC 69 with IEC CISPR/B having responsibility for emissions during charging. All of the activities are to take into account the basic IEC/TC 77 EMC standards (the IEC 61000 series) where appropriate.

In terms of EMC standards for the electric grid, the main source is the IEC 61000 series. The 61000 series has several parts that cover everything from the general application of the standard (part 1), through discussions of environment, limits, testing and measurement, installation and mitigation, and finally a generic catchall volume (parts 2 through 6 respectively). Propagated by various subcommittees of IEC/TC77, Electromagnetic compatibility, between electrical equipment including networks, the 61000 series has broad applicability in the infrastructure segment of the EV space.

IEC CISPR/D and ISO/TC22/SC3/WG3 have been meeting back-to-back on a regular basis to address the vehicle EMC issue while not connected to the power grid. CISPR has a liaison relationship with IEC/TC69. In addition, CISPR/B has been interacting with IEC/TC 69 in regard to emissions and the applicability of CISPR 11 during charging.

The SAE Surface Vehicle EMC (SV) Standards Committee is also addressing EMC issues. Subsets of this committee form the U.S. TAGS for CISPR/D and ISO/TC22/SC3/WG3, respectively. There are SAE product committees that are addressing the charging of electric vehicles. SAE J1772™ includes EMC requirements for the conductive charging interface unit, referring to UL 2231-2 and FCC part 15. SAE J2954 is under development and will address inductive charging of electric vehicles. The SV EMC Standards Committee is supporting the J2954 document development in regard to rf issues.

EMC issues related to electric vehicles in the United States and in the international arena are being actively addressed. No gaps have been identified with respect to this issue at this time. If there are environmental or operating conditions that need to be addressed, these should be brought to the attention of the existing automotive standards groups.

4.2.1.5 Vehicle as Supply

SAE standards J2836/3™ and J2847/3 identify the architecture, use cases and safety aspects for reverse power flow (RPF) and the use of the EV as a Distributed Energy Resource (DER). The general information is included in J2836/3™ with the corresponding message and sequence diagrams in J2847/3. The customer interfaces and selection for these features will be included in J2836/5™ and J2847/5. The /5 documents include the two networks that are: (1) the Customer Network for Customer to EV and Home Area Network (HAN)/Neighborhood Area Network (NAN) interface and (2) the Utility Network for Energy Services Interface (ESI) to EVSE/EV communication. As with the /3 documents, J2836/5™ identifies the use case and general information that corresponds to J2847/5 for messages details. This is a coordinated effort of the EV, EVSE and ESI for the various combinations of RPF.

V2H, V2L, and V2V do not require infrastructure communication. Infrastructure communication is required for advanced functions of V2G when the EV serves as a DER. As SAE J1772™ and IEC 61851 are updated to address RPF, the architecture and safety aspects within J2836/3™ are expected to be moved to these standards.

Section 625.26, Interactive Systems, of the NEC® provides that EVSE and other parts of a system, either on-board or off-board the vehicle, that are identified for and intended to be interconnected to a vehicle and also serve as an optional standby system or an electric power production source or provide for bi-directional power feed shall be listed as suitable for that purpose. When used as an "Optional Standby System" (i.e., V2H), the requirements of Article 702 shall apply, and when used as an "Electric Power Production Source" (i.e., V2G), the requirements of Article 705 shall apply. The on-board or external inverter is considered to be a "Utility-Interactive Inverter" for which there are special requirements in the NEC®. The NEC® adequately provides for an EV serving as either a standby system or a grid interactive system and changes to the NEC® specifically to accommodate EV applications are not anticipated.

The safety standard UL 1741, Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources, applies to an EV engaged in V2G. For utility-interactive equipment, UL 1741 is intended to supplement and be used in conjunction with IEEE 1547™, Standard for Interconnecting Distributed Resources with Electric Power Systems, and IEEE 1547.1™, Standard for Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems.

IEEE 1547.4™, Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems, was released in July 2011 and may apply to certain V2G applications. IEEE 1547.8™, Recommended Practice for Establishing Methods and Procedures that Provide Supplemental Support for Implementation Strategies for Expanded Use of IEEE Standard 1547™, is currently being developed and will introduce new advanced capabilities for utility-interactive inverters that could also impact V2G operations. Updates to Article 705 of the NEC® and UL 1741 may be required to accommodate new DER capabilities.

Gap: **Vehicle as supply / reverse power flow.** Standards to address communications and safety aspects of reverse power flow in V2G, V2H, V2L and V2V applications are still in development.

Recommendation*:* Complete work to address communications and safety aspects of reverse power flow in SAE J2836/3™ and SAE J2836/5™, and SAE J2847/3 and SAE J2847/5. Address reverse power flow safety aspects in IEEE standards. ***Priority:*** Near-term. ***Potential Developer:*** SAE, IEEE.

4.2.1.6 Use of Alternative Power Sources

Much of the focus has been about electric vehicle charging using the bulk electric power system. But there may be cases where alternative power sources could be used to provide power for charging an EV. A solar PV array, small wind turbine, facility battery bank, or even another EV with reverse power flow capability could be used to provide power for charging an EV in a facility. These alternate sources could operate as optional standby systems under Article 702 of the NEC or as an electric power production sources under Article 705 of the NEC and provide AC power to the facility. The AC power could be used for charging EVs and for other loads within the facility. However, it may be more efficient to use DC power distribution rather than AC power distribution for this purpose. All of the facility power sources as well as certain DC loads could connect to a DC power distribution system which would connect to the electric power system using a single converter.

The EMerge Alliance is developing standards for a 380 VDC power distribution system. 600 VDC systems have also been considered for use with PV arrays. It is not possible to directly connect an EV to a facility DC power bus because of differences between the EV battery voltage and the facility bus voltage and the need to precisely control the charging current into the EV battery. However this is easily done using a DC to DC converter, such as a buck-boost converter. The EVSE for DC charging is generally thought of as an AC-DC converter, or bidirectional converter for reverse power flow, but a DC-DC EVSE could easily be used if the facility used a DC power distribution system.

Solar: ANSI/UL 1703, the standard for safety of photovoltaic (PV) equipment, and other UL standards, address safety of PV modules. The National Electrical Code® contains requirements for PV systems in Article 690. Car “sheds” with PV panel roofs and directly coupled EVSE beneath are being constructed but are not specifically covered by standards at this time.

Wind: Small wind systems are addressed in NEC® Article 694. Consensus product standards are under development for wind systems and should be published shortly. Wind power as a supply source is also the subject of a proposed revision to the NEC® to include DC voltages up to 600 volts.

Battery banks: Battery banks are another alternative source of DC power. They can be charged off-peak and used to charge vehicles directly. Battery banks are being addressed by a code proposal on NEC® Section 625.4 to include power sources up to 600 volts DC.

V2G and V2H: As discussed in the prior section, Vehicle to Grid (V2G) and Vehicle to Home (V2H) power schemes have been discussed and anticipated. The reserved energy in an EV battery may be used for power quality, power efficiency, or emergency source measures. Articles 702 and 705 of the NEC® would apply to how the entire DC system connects through the utility-interactive inverter to the electric power system, but there is a gap for requirements between the EV and EVSE and the DC power distribution system.

Gap: **Use of alternative power sources.** The National Electrical Code® does not specifically address the integration of the EV and EVSE with a facility high voltage DC power distribution system for either charging or reverse power flow.

Recommendation*:* Develop NEC® requirements for high voltage DC power distribution systems and the integration of distributed energy resources and DC loads with the system. ***Priority:*** Near-term. ***Potential Developer:*** NFPA.

4.2.2 Infrastructure Communications

Communications Standards

Most of the completed and ongoing standardization related to communications for EV charging infrastructure has taken place within SAE International and the ISO/TC 22/SC 3 – IEC/TC69 Joint Working

Group (JWG) developing the ISO/IEC 15118 standards. Other standards such as Smart Energy Profile 2.0 (SEP 2.0), in development by the ZigBee Alliance and the HomePlug Powerline Alliance, and Open Automated Demand Response (OpenADR), in development by the Open Smart Grid User's Group (OpenSG), are also incorporating EV charging-related communications.

Currently, charging-related communication between the EV and EVSE for conductive charging has been standardized in SAE J1772™ (and in IEC 61851-1). This communication is used to signal the readiness of the EV to accept energy and of the EVSE to supply energy. It also allows the EVSE to determine if the EV requires indoor ventilation and to signal the ampacity (maximum allowable current) that the EV should consume. Verification of the connection, equipment grounding continuity, and proximity detection are also provided.

SAE is currently developing standards for EV communication that go beyond SAE J1772™ and define communications functions for utility communications, DC charging, reverse power flow, diagnostics, Customer-to-EV/HAN/NAN, and wireless charging. Figure 7 shows the interaction between the SAE EV communications standards documents. These can be stand-alone (e.g., DC charging) or combined (reverse power flow with off-board conversion includes both SAE J2847/2 plus /3 messages). The figure uses a Venn diagram approach to show the fundamental documents (SAE J2836™, J2847 & J2931) "wrapped" by the interoperability document(s) J2953 and finally the security document J2931/7.

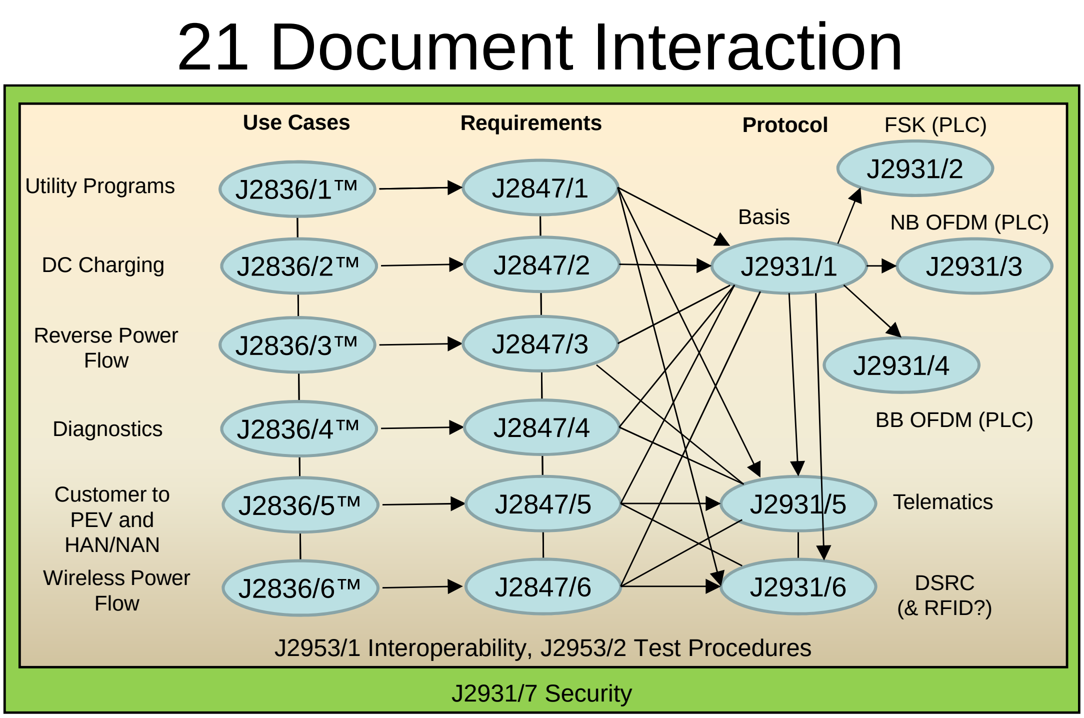

Figure 7: The Interaction of SAE EV Communication Standards Documents
(Used with Permission of SAE International)

These documents have various slash sheets to keep the functions separated and concise, and yet build on each other depending on the functions desired. SAE J2836™ includes the use cases and general information for each function. SAE J2847 includes the corresponding slash sheets that use the requirements defined in SAE J2836™ and adds messages, sequence diagrams, and other details. SAE J2931 includes the communication protocol for various mediums including power line communication (PLC), telematics, and dedicated short range communication (DSRC) for use in the messages of J2847.

SAE J2931/3 is based on the G3-PLC specification which is also the basis for IEEE 1901.2. J2931/4 is based on HomePlug Green PHY™ which is an interoperable subset of IEEE 1901-2010 (which is, in turn, based on HomePlug AV). EPRI and the DOE national labs are testing PLC products to ensure that the technology meets the requirements in J2931/1. Additional testing is planned by vehicle manufacturers. EMC testing and standards implementation via field testing will provide feedback prior to a final determination leading to standards updates and a production release for PEVs and EVSEs.

SAE J2953 identifies the interoperability criteria for the various mediums (PLC, telematics, DSRC, etc.) and associated communications protocols identified in J2931. Security is included specifically in J2931/7 and may have slight variations dependent on Smart Energy Profile (SEP) 2.0 utility requirements, DC charging/discharging, and where the PEV is controlling the off-board unit for wireless charging communication.

Harmonization Efforts

The ISO/IEC Joint Working Group (JWG) is working on EV communication standards concurrently with SAE. The ISO/IEC 15118 EV communications standards are related to the SAE documents as follows: ISO/IEC 15118 identifies dash 1 for use cases, dash 2 for message details, and dash 3 for physical and data link communications layers. ISO/IEC 15118-1 corresponds to SAE J2836™, 15118-2 to SAE J2847, and 15118-3 to SAE J2931. ISO/IEC 15118-3 currently contains equivalent annexes for GreenPHY (Annexes B&D) and G3-PLC specifications (Annexes C&E). The ISO/IEC 15118 series also includes DC charging use cases and messages that correspond to dash 2 of SAE J2836™ and J2847.

In addition to the SAE and ISO/IEC standards, the Smart Energy Profile (SEP) 2.0 specification, based on the OpenHAN requirements, is expected to provide much of the EV-related services identified by regulators, policy makers, ESPs/utilities, EVSPs and vendors. Though not EV specific, this standard-in-progress pertains to communication between the ESP and EVSP, and the energy-related infrastructure (e.g., thermostats, plugs, meters, displays, EVSE, EV, etc.). It specifies layer 3 and above communications to be used for pricing, demand response load control (DRLC), distributed energy resources (DER) control, metering, billing, and other functions. SEP 2.0 is harmonized with J2836/1™ and is being used as the basis of J2847/1.

In addition to the coverage of DRLC in the SEP 2.0 specification, Open Automated Demand Response (OpenADR) 2.0 contains EV-specific communication and is expected to be harmonized with SEP 2.0 for building infrastructure communication. It is anticipated that ESPs, and possibly EVSPs, will use OpenADR for their automated demand response requirements.

For open and interoperable machine-to-machine (M2M) communication between entities such as ESPs and EVSPs related to EV customer information (e.g., for pricing, metering, billing, and usage information), the North American Energy Standards Board (NAESB) has completed work on the Energy Services Provider Interface (ESPI) standard.

The ISO/IEC JWG and Zigbee Alliance / HomePlug Powerline Alliance are working with SAE to harmonize common standards related to utility and DC messaging.

SAE utility messages (SAE J2847/1) correspond with the SEP 2.0 criteria per the Smart Energy 2.0 Technical Requirements Document (TRD) and the Application Specification that has now passed public comment approval. SAE's J2836/1™ use cases were included in the ZigBee + HomePlug Smart Energy Marketing Requirements Document (MRD) that led to the TRD.

SAE is also working on the DC message format with the objective of harmonizing with ISO/IEC. DC charging information in SAE J2847/2 is being included in Annex C of IEC 61851-24, and ISO/IEC 15118-2 is being included in Annex D. In the future, these annexes may be replaced by a harmonized solution in the body of the IEC 61851-24 document. As PLC testing continues, it is expected that goals can be met and both utility and DC charging messages can be harmonized.

Finding, Reserving, and Using Public Charging Stations (EVSE)

Public charging stations are already available and in use; however, there is no standardized method to identify the location and capabilities of a charging station. Presently, such a capability is available for only a subset of stations via Google Maps, websites of EVSPs, smartphone applications, or navigation applications/devices. Notably, DOE provides an Alternative Fuel Station Locator database which includes EV charging station information at: http://www.afdc.energy.gov/afdc/locator/stations/.

A well-known registry of public charging stations combined with a standardized querying method would enable the broadest public awareness and utilization. It is likely some information about a charging station will be static (e.g., location, type) and can be queried from a global registry, but other information (availability, pricing) will be dynamic and must be queried from the station or the managing entity.

Reserving Charging Stations (EVSE): Due to the relatively long duration of EV charging, the ability to reserve a charging station in advance will be useful to EV drivers. Standardization of the messaging required to reserve a charging station would allow a driver to use a variety of methods (smartphone application, web site, etc.) to reserve a station.

Gap: **Locating and reserving a public charging station**. There is a need for a messaging standard to permit EV drivers to locate a public charging spot and reserve its use in advance.

Recommendation: Develop a messaging standard to permit EV drivers to universally locate and reserve a public charging spot. ***Priority***: Mid-term. ***Potential Developer***: SAE, ISO/IEC JWG, NEMA.

Roaming: Public charging stations may be owned by hosts and managed by EVSPs. EV drivers may subscribe to a charging plan offered by an EVSP (the Home EVSP). Roaming, in the context of EV charging, is the ability to charge at a charging station managed by a different EVSP (Visited EVSP), using the subscription to the Home EVSP.

Communication related to roaming scenarios may take place directly between two EVSPs. Alternatively, a third-party financial clearing house may be required to act as an intermediary between the Home EVSP and Visited EVSP(s). In order to support roaming scenarios, standardization is required for authentication of the EV/driver, authorization of the EV/driver for a certain quality of service, relaying of accounting records related to the charging session, and settlement of billing.

Gap: **Charging of Roaming EVs between EVSPs**. There is a need to permit roaming EVs to charge at spots affiliated with a different EVSP.

Recommendation: Develop back end requirements as well as an interface standard that supports charging of roaming EVs between EVSPs. ***Priority***: Near-term. ***Potential Developer***: NEMA, IEC.

Access Control: In some cases, charging station owners may choose to restrict use of their charging stations. For example, an enterprise may restrict daytime charging to employees only, and allow non-employees to charge at night or during weekends. There are two aspects of aspect control that can benefit from standardization. First, a standard definition of access control data and standard messaging to communicate the access lists to EVSEs would ease implementation of access control across EVSE vendors. Second, the ability to communicate access lists to EVSEs would allow for offline access control checks for situations when network connectivity of an EVSE is down.

Gap: **Access control at charging stations**. There is a need to develop data definition and messaging standards for communicating access control at charging stations.

Recommendation: Develop data definition and messaging standards for communicating access control at charging stations. ***Priority***: Near-term. ***Potential Developer***: NEMA.

Telematics - Communications Interoperability

Telematics offers great potential for charge management of electric vehicles individually and collectively and as a flexible generation source for utility load management in the smart grid era. Telematics can also provide a number of other benefits including the ability to locate/reserve charging stations, communicate utility price signals, and facilitate vehicle diagnostic services.

The scope (and definition) of telematics needs to be defined. If it is B2B communication between energy service providers and telematics service providers (as suggested by the SAE J2931/5 scope), then that communication is already being standardized within OpenADR 2.0, ESPI, and SEP 2.0 (which meet identified energy service provider requirements). If the scope is from telematics providers to PEV, HAN, etc., then there are probably additional requirements (like aggregation, reserving charging stations, etc.) needing to be met. Relevant standards may include: SAE J2931/5, J2836/5™ and J2847/5 which will address the communication protocol and features for individual or aggregated vehicle management by EV telematics service providers.

Discussion of this issue will continue. No gap has been identified at this time.

Communication of Standardized EV Sub-metering Data

The basis of the following assessment is for billing purposes only although metering communication could be used for customer information and control through the HAN (e.g., using SEP2.0) or vendor provided value added services (e.g., using smart phone applications).

The method through which EV meters communicate consumption depends on regulatory and business policies, how the meter is set up, and the communication capabilities of the system infrastructure. If the End Use Measurement Device (EUMD) is a separate (parallel) meter, as is currently offered by many utilities today for EV time of use (TOU) rates, existing communication would most likely be used (e.g., utility Advanced Measurement Interface (AMI) systems).

Sub-metering, whereby the EUMD is located on a branch circuit from the premises meter, could possibly utilize many different types of communications. If the sub-meter is utility provided, proprietary AMI systems could be used to communicate directly to back office systems or through the premises meter (e.g., using Zigbee mesh communications). From a security standpoint, allowing non-utility provided sub-meters onto existing AMI networks would be based on utility policies and/or regulations. Once established, the SEP 2.0 HAN standard could be implemented on the sub-meter to mirror EV meter data to the main meter and sent to back office systems using AMI.

Another sub-meter communication option currently being explored by the California Public Utilities Commission (CPUC) uses the Energy Service Provider Interface (ESPI) standard. The CPUC has ruled that sub-meters are to be non-utility provided (customer or 3rd party owned). California investor owned utilities, 3rd parties, and customer groups are working on an implementation strategy whereby the sub-meter communicates EV information to the 3rd party (meter reader), who communicates to the utility through the ESPI interface. Communication between the meter and the 3rd party could be proprietary or could be based on an existing or expected metering communication standard (e.g., ANSI C12 developed by NEMA (ASC/C12), SEP 2.0). Another option is being explored whereby the meter implements ESPI and communicates the EV information directly to the utility ESPI interface.

Mobile sub-metering, which refers to sub-meters within EVs or combined with 110V or 220V cord sets that can be transported and exchanged, provides additional complexities. Pre-authorization would be required if an EV consumed energy at a visited premises but was to be billed to the owner's home account. This pre-authorization would have to be on file with the utility to subtract the energy used by the EV from the bill of the visited premises. Additionally, the vehicle must associate with that premises and both the vehicle's ID and premises meter or account ID must be communicated with the utility. This would involve local association (e.g., PLC or HAN technology). If the vehicle is travelling outside of the territory for which it has an associated service account, utilities will most likely have to share customer and consumption information. Similar to premises meters, mobile metrology could be communicated using either a proprietary or standardized communication method (e.g., telematics or SEP 2.0 for 3rd parties, and AMI, ESPI, or SEP2.0 for utilities), depending on regulatory and utility policies.

Gap: **Communication of standardized EV sub-metering data**. Standards for communication of standardized EV sub-metering data are needed.

Recommendation: Continue work to develop standards for communication of standardized EV sub-metering data. ***Priority***: Near-term. ***Potential Developer:*** ZigBee Alliance, NAESB

4.2.3 Infrastructure Installation

4.2.3.1 Site Assessment/Power Capacity Assessment

The National Electrical Code® (NEC®) provides minimum requirements for performing site assessments, specifically NEC® Articles 210, 215, and 220 contain rules that relate to calculations and loading of services, feeders, and branch circuits in all occupancies. AC Level 1 and AC Level 2 EVSE are considered continuous loads with the maximum current expected to continue for 3 hours or more. Pursuant to a Tentative Interim Amendment (TIA) to the 2011 NEC®, if an automatic load management system is used, the maximum electric vehicle supply equipment load on a service or feeder shall be the maximum load permitted by the automatic load management system. If there is no load management, then they must be sized for 125% of the maximum current. Fast-charging EV supply equipment operates for less than 3 hours but is calculated at 125% of the nameplate current rating. Section 625.14 of the NEC® contains additional provisions related to the load calculations for EVSE.

In conducting a site/power capacity assessment for existing facilities (residential, commercial, and industrial), the following needs to occur:

- Conduct site visit;
- Inventory electrical equipment;
- Interview the facility occupants to determine the cyclical daily and seasonal loading of the facility;
- When available, review a minimum of 12 months of electric utility bills to determine the maximum demand for incorporation into load calculations; and
- Verify by calculation the existing loads on the service or system. For commercial installations, consideration for future expansion and multiple EVSE should be included in load calculations. Involve electrical utility planners early in the process when planning EVSE for fleet applications.

<u>Site Assessment Verifies Locations and Other NEC® Requirements</u>

The site assessment is also required to verify acceptable location(s) of the EVSE and conformance with the NEC® and other applicable codes such as the International Residential Code® for One- and Two-Family Dwellings (IRC®), International Building Code® (IBC®), Americans with Disabilities Act (ADA) requirements (ICC/ANSI A117), and any other state or local zoning regulations. Note that local codes and regulations may be more restrictive than national codes and must be verified with the applicable jurisdiction. This can be determined during the permitting process for installation.

Other NEC® Rules and Installation Standards

The NEC® also provides the minimum requirements for service equipment, overcurrent protection, grounding and bonding, appropriate wiring methods, and locations or occupancy types that are often determined as part of a site assessment. Branch circuit or feeder wiring method can vary depending on the EVSE installation location. A National Electrical Installation Standard (NEIS) currently in development, NECA 413 Standard for Installing and Maintaining Electric Vehicle Supply Equipment (EVSE), provides detailed information about performing site assessments and installation of EVSE in new and existing electrical systems. NECA 413 covers the following related to performing effective site assessments:

- Supply Equipment/Charging Power Selection: AC Level 1, AC Level 2, Fast Charging;
- Charging Equipment (Type): Conductive, Inductive;
- Service or Power Capacity (load on new and existing systems or services);
- Electrical Load Calculations;
- Site Selection and Preparation;
- Zoning and Site Restrictions;
- Sites for Fleet Charging Installations;
- Energy Code Requirements;
- Mechanical Ventilation (where required);
- Electric Utility Interconnection Installation Requirements;
- Utility Interactive EVSE Installation;
- Special Metering or Special Metering Equipment Installation; and
- Time of Use or Off-Peak Metering Installation(s).

Some specific installations under the exclusive control of an electric utility are excluded from the scope of the National Electrical Code® (NEC®) and fall under the scope of ANSI C2, the National Electrical Safety Code® (NESC®). These are generally locations where the utility-owned installations are on legally established easements or rights-of-way. The NESC® is a code that is primarily used for generation, transmission, distribution, and metering of electrical energy. However, the National Electrical Code® (NEC®) applies to some installations that are owned by electric utilities including utility owned office buildings and garages. The addition of electric vehicles may necessitate the need for a utility infrastructure upgrade to achieve an adequate power supply.

The site/power capacity requirements for EVSE connected to an electric service or other power source are already well covered in the NEC®. The permit process usually captures any issues related to the site as far as zoning or suitable locations for EVSE.

No gaps have been identified at this time with respect to this issue.

Harmonization Efforts

A harmonization assessment has been conducted examining NEC® Article 625, the Canadian Electrical Code, and IEC 60364 to identify parallel sections which have already been harmonized and those which may still need to be. This effort is nearly complete.

4.2.3.2 EV Charging and Parking - Urban Planning

Currently, the model International Green Construction Code™ (IgCC™) has an elective provision requiring that for covered buildings 5 percent of, but not less than two, parking spaces shall be reserved for low emission, hybrid and electric vehicles (IgCC™, PV2, Sec. 403.4.2). There are no current standards or model code provisions within either the IBC® or IgCC™ requiring EV only parking or charging. At some point, this may be desirable. Recommendations for new code provisions would have to be made and accepted as part of the normal code revision cycle. The state of California does have a law that governs electric vehicle charging station parking.

No gaps have been identified at this time with respect to this issue.

Harmonization Efforts

As urban planning is a localized activity, harmonization is generally not a relevant issue.

Conformance Programs

Most jurisdictions in the United States regulate parking issues at the local level without reference to national standards. This is accomplished through ordinances and accompanying regulations including various means of enforcement (mechanical and electronic), as well as civil and criminal requirements and penalties. No gaps have been identified at this time.

4.2.3.3 Charging Station Permitting

Normally the installation of EVSE is governed under a construction permitting process of the applicable authority having jurisdiction, which could be a state, city, county, town, or other municipality. Often the local jurisdiction has knowledge of additional permits necessary and advises this during the initial permitting application process.

Another condition that may necessitate additional permits for installing EVSE is when the equipment is located in public right-of-ways. In these cases, a state, county, or city may require a right-of-way work permit and inspection. There may also be right-of-way specifications by the permit-issuing entity. Airports, train stations, bus stations, and other public transit depots may have specific owner permits that are required, in addition to the city, county, or state permit required for installation safety.

Residential Permitting: The primary purpose of the permitting process is to ensure an installation that is safe from shock and fire hazards, as well as the potential for physical damage. EVSE installations are a significant continuous duty load. Older homes may not have the capacity to safely supply the load. Even some more modern homes with electric heating or air conditioning may be near their capacity limit.

The permitting process involves a review of the plans and an on-site inspection to ensure compliance with the requirements of the National Electrical Code® (NEC®), published by NFPA. The NEC® is widely adopted, and is also referenced in the International Residential Code® for One- and Two-Family Dwellings (IRC®), published by ICC, that is used as the basis for regulation of residential buildings in all 50 states, at the state or local level. Provisions exist in the 2011 NEC® to cover EV charging systems and their installation. The DOE Clean Cities program has published information on its website which may be used as a starting point for jurisdictions looking to establish permitting procedures for EVSE.

Commercial/Public Permitting: The permitting process is also important for nonresidential installations. Capacity of the electrical system is also a concern in these occupancies, particularly where there are multiple EVSE that may be in use. Fire and shock hazards are a concern. There is also a higher risk of vehicle damage and the potential for exposure to other hazards.

The permitting process will verify electrical system capacity and compliance with the requirements of the NEC®. The NEC® is referenced in the International Building Code® (IBC®), published by ICC, which is used as the basis for regulation of commercial buildings and residential buildings of 4 stories or greater in most states, at the state or local level. As noted, provisions exist in the NEC® to cover EV charging systems and their installation.

No gaps have been identified at this time with respect to this issue.

Harmonization Efforts

No gaps have been identified at this time as permitting is a local issue and as such does not really lend itself to harmonization.

Conformance Programs

In the U.S., conformance with electrical and building codes relies on three inter-related mechanisms: applicable installation codes and standards, product safety standards and certifications, and plan approval and inspection. Each of the three components is considered critical to electrical and building safety, and the system is compromised if one of the three is missing. While there may be some variations in policies and procedures among jurisdictions, the three elements described are common to most jurisdictions and have been largely successful in achieving safe buildings. While checklists can be of assistance to jurisdictions in helping to assess conformance with common requirements, they should be considered a starting point so that jurisdictions can address specific or unique concerns in their inspection regimens.

No gaps have been identified at this time.

4.2.3.4 Environmental and Use Conditions

Product standards such as UL 2594, the Standard for Safety of Electric Vehicle Supply Equipment, generally anticipate maximum ambient temperatures of 40C, although higher limits may be declared by manufacturers and validated in the testing. This is consistent with widespread use of a 40C default ambient threshold for industrial and similar equipment. Product testing generally includes consideration for lower ambient levels, such as -30C, for particular test conditions.

Exposure to the elements is generally addressed by established test methods, such as the NEMA enclosure type designations and related testing. Environmental considerations are also addressed in UL 50E, Enclosures for Electrical Equipment, Environmental Considerations.

Exposure to corrosive agents for EV infrastructure equipment is addressed in various ways by product standards, generally in consideration of the degrading effects of exposure to the elements, anticipated fumes or solvents, and/or anticipated compounds such as gasoline fuels that may be present in vehicular locations.

Use of equipment, including electric vehicle supply equipment, in hazardous (classified) locations is addressed by well-established requirements. These requirements mitigate the potential fire or explosion hazards by various strategies to minimize the risk of an electrical circuit from serving as a source of ignition for the potentially hazardous gases, vapors, or other sources. The established requirements include numerous product standards relevant to the use of the equipment in particular classified locations, and installation requirements in Chapter 5 of the National Electrical Code®.

Electric vehicles will be exposed to many of the same hazards as conventionally powered vehicles. The principal difference is that EVs are a source, as well as a user of large amounts of electrical energy. EVSE installation must consider all of the potential environmental as well as occupancy exposures. For example, in a parking garage, there may be more potential for exposure to vehicle impact damage. Parking garages may be required to comply with NFPA 88A, Standard for Parking Structures, or with Section 406 of the International Building Code® (IBC®), Motor Vehicle Related Occupancies. Which code or standard applies depends on which code or standard the particular jurisdiction has adopted.

Another example would be that electric vehicles are likely to use automotive service stations. Parts of these stations are considered to be hazardous locations in accordance with NFPA 30A, Code for Motor Fuel Dispensing Facilities and Repair Garages, Article 514 of the National Electrical Code®, and Section 307 of the International Building Code® (IBC®). Exposure to this type of hazard will require the compliance with additional requirements in Articles 500, 501, and 514 of the NEC® to ensure that EVSE does not become an explosion hazard.

Other applicable hazards also need to be considered. Location of the EVSE installation away from hazards is the primary means to minimize risk.

No gaps have been identified at this time with respect to this issue.

4.2.3.5 Ventilation - Multiple Charging Vehicles

Most batteries used in electric vehicles manufactured by major automakers do not emit hydrogen gas in quantities that could cause an explosion. Preventive measures such as mechanical or passive ventilation are not required.

<u>SAE Standards</u>

SAE International's recommended practice SAE J-1718, Measurement of Hydrogen Gas Emission from Battery-Powered Passenger Cars and Light Trucks During Battery Charging, can be used to assess suitability for indoor charging. This standard includes provisions for tests during normal charging operations and potential equipment failure modes.

<u>NEC® Code Provisions</u>

Some electric vehicles will require ventilation because they use batteries that generate hydrogen. Section 625.29(D) of the NEC® has requirements for ventilation for single and multiple vehicles, and Section 625.15(B)&(C) provides ventilation labeling requirements for EVSEs.

<u>ICC Code Provisions</u>

The model International Residential Code® for One- and Two-Family Dwellings (IRC®) has specific requirements regulating ventilation requirements for "hydrogen generating and refueling operations." Such requirements could be referenced or modified for similar ventilation issues, should they exist with respect to EV charging operations. The IRC® scope includes one and two family dwellings, as well as multi-family dwellings of three stories or less in height.

The model International Building Code® (IBC®) has provisions requiring a ventilation system in all "Enclosed Parking Garages." The ventilation system must meet requirements of the International Mechanical Code® (IMC®), which is referenced in the IBC®. The IBC® scope includes all commercial buildings, as well as all residential buildings of more than 3 stories in height.

No gaps have been identified at this time with respect to this issue.

Conformance Programs

Most jurisdictions currently issue permits and inspect parking garages through building code enforcement permitting and inspection processes that are well-established and well understood. No gaps have been identified at this time with respect to this issue.

4.2.3.6 Guarding of EVSE

In general, available information with regards to guarding of EVSE is limited. Currently, it does not appear that the National Highway Traffic Safety Administration (NHSTA) or the American Association of State Highway and Transportation Officials (AASHTO) have initiated development of guidelines or standards for EVSE guarding. NFPA 730, Guide to Premises Security, addresses security in all occupancies from residential dwellings to large industrial complexes. Provisions describe construction, protection, and occupancy features and practices intended to reduce security risks to life and property. Specifically, Annex E is an informative annex which discusses the placement/design of bollards. Another issue is when to design for physical protection as opposed to designing for a break-away scenario if a vehicle from a nearby roadway collides with the EVSE.

Gap: **Guarding of EVSE.** There is a lack of standards that address charging station design with respect to physical and security protection of the equipment.

Recommendation*:* Guidelines or standards relating to guarding of EVSE should be developed. ***Priority:*** Mid-term. ***Potential Developer:*** NHTSA or AASHTO.

4.2.3.7 Accessibility for Persons with Disabilities to EVSE

Accessibility and compliance with requirements for accessibility in adopted building codes, and state or federal accessibility requirements, i.e., the Americans with Disabilities Act (ADA) and Fair Housing Act (FHA), is an issue for EVSE. According to the Electric Drive Transportation Association, the "ADA does not specifically prescribe standards addressing the installation of charging infrastructure; however, it does provide general guidance in sections 206, 208, 403.5 and 502 related to routes, clearances, and parking spaces."[4] While some states have developed guidelines related to charging station accessibility, enforcement rests with the local authority having jurisdiction.

Gap: **Accessibility for Persons with Disabilities to EVSE.** There is a lack of standards that address charging station design with respect to accessibility for persons with disabilities to EVSE.

[4] http://goelectricdrive.com/Resources/Accessibility.aspx

Recommendation: Guidelines or standards relating to accessibility for persons with disabilities to EVSE should be developed. ***Priority:*** Mid-term. ***Potential Developer:*** ICC (ASC A117 and IBC®).

4.2.3.8 Cable Management

Functional management of EV cables in public parking spaces is not specifically addressed by codes or standards.

EVSE standards, including ANSI/UL 2251, the Standard for Safety for Plugs, Receptacles and Couplers for Electric Vehicles, and the National Electrical Code®, contain requirements for breakaway protection of cables.

ANSI/UL 355, the Standard for Safety of Cord Reels, covers cord reels for general use, as well as special-use cord reels intended to be mounted on or in electrical utilization equipment such as appliances or similar equipment.

Section 406 of the IBC® addresses Motor-Vehicle-Related Occupancies, with 406.2 addressing parking garages; however, cable management is not specifically addressed.

Security of EVSE cables, including means to discourage theft of copper cables from EVSE, is not specifically addressed at this time. Attempted theft of EVSE cables may also lead to potential safety hazards.

Gap: **Cable management.** There is a lack of standards or code provisions that address functional management of EV cables in public parking spaces.

Recommendation: Guidelines or standards relating to EVSE cable management should be developed. ***Priority:*** Mid-term. ***Potential Developer:*** UL, NFPA.

4.2.3.9 EVSE Maintenance

NECA 413, a national electrical installation standard (NEIS) currently in development, provides information with regards to maintaining EVSE. Specifically, Chapter 7 discusses maintenance in accordance with manufacturers' recommendations and provides guidelines for the care of EVSE, including periodic inspections for wear, damage, and vandalism, as well as cleaning.

NFPA 70B, Recommended Practice for Electrical Equipment Maintenance, applies to preventive maintenance for electrical, electronic, and communications systems and equipment. Systems and equipment covered are typical of those installed in industrial plants, institutional and commercial buildings, and large multifamily residential complexes. NFPA 70B is not intended to duplicate nor supersede manufacturer instructions for maintenance.

No gaps have been identified at this time with respect to this issue.

4.2.3.10 Workplace Safety Installation

There are multiple published standards and codes that include general and specific requirements for safety in the workplace. The process of installing and maintaining EVSE must include application and implementation of all workplace safety rules and specifically electrical workplace safety requirements as provided in NFPA 70E-2012, Standard for Electrical Safety in the Workplace. The U.S. Government includes in the Code of Federal Regulations minimum requirements for workplace safety.

Minimum safety requirements for General Industry are provided in Part 1910, Occupational Safety and Health Administration (OSHA) Standards Subpart S – Electrical. Subpart S includes general information, design safety standards for electrical systems, safety-related work practices, safety-related maintenance requirements, safety requirements for special equipment, definitions, and reference documents in Appendix A. Minimum safety requirements for electrical construction are provided in Part 1926, OSHA Subpart K – Electrical. Subpart K includes general information, installation safety requirements, safety-related work practices, safety-related maintenance and environmental considerations, safety requirements for special equipment, and definitions.

No gaps have been identified at this time with respect to this issue.

4.3 Support Services Domain

4.3.1 Education and Training

Standards and education and training are important elements needed to ensure the safety and security of electric vehicle owners and those who service the vehicles or respond to vehicle emergencies, and to ensure safe EVSE installations, and consistency of information.

Much of the information needed by personnel who respond to emergencies or service EVs and associated equipment is contained in OEM or other manufacturer information. There are standards for professional qualifications for rescue technicians and incident managers (NFPA 1006 and 1026) but these cover generalized skills and safe methodologies without getting into the specifics of vehicles or equipment.

4.3.1.1 Vehicle Emergency Shutoff, Including Labeling of High Voltage Batteries, Power Cables, and Disconnect Devices

While there are equipment performance and test standards for high voltage electric vehicle battery disconnect devices, there do not appear to be any standards for safety labeling of batteries or disconnect devices or their locations in electric vehicles.

It has been suggested that markings on EV batteries and disconnect devices could be graphical (language neutral) and color-coded so that they can be quickly and easily identified. And that disconnect devices should be designed to protect against the possibility of arcing faults during disconnecting operations, and not require arc flash personal protective equipment to be worn when operated.

SAE has a standard on color coding of cabling in the 30-60 volt range and for high voltage cabling.

High voltage cabling in EVs is unlikely to become standardized in terms of location or routing. However, the routing of EV cables is documented in shop manuals and emergency response guides (ERGs) provided by vehicle manufacturers.

It is important that the OEMs specify in their ERGs the location of EV battery and disconnect devices, and proper procedures/sequencing to shutoff power to the vehicle.

SAE has a taskforce (J2990) looking at recommended practices for first and second responders with HEV and EV vehicles that will help to fill some gaps when published. This is work in progress with a target publication date of Fall 2012.

Partial Gap: **Vehicle emergency shutoff, including labeling of high voltage batteries, power cables, and disconnect devices.** Standards are needed in terms of safety labeling of high voltage batteries, power cables, and disconnect devices.

Recommendation: Develop standards for safety labels for electric vehicle batteries, power cables, and disconnect devices to enable emergency responders and service personnel to quickly and easily recognize them and to avoid electrical shock hazards. ***Priority:*** Near-term. ***Potential Developer:*** NFPA, SAE, ISO, IEC.

Harmonization Efforts

CEN/CENELEC in their October 2011 report recommended increased efforts to ensure emergency services are able to respond appropriately with respect to battery hazards caused by the use of electric vehicles, mechanical impact to the batteries, and exposure of batteries to fire or water. The report also noted that there is no unified language for safety labeling regarding EV batteries. The EU recognizes the need to standardize labels and graphics for the protection of first responders to deal with incidents, but no appropriate standards now exist in Europe.

4.3.1.2 Labeling of EVSE and Load Management Disconnects

No standards currently exist for labeling residential/commercial/public EVSE devices and disconnect locations. Such information would be particularly useful during emergencies. NFPA 70®, the National Electrical Code®, is an ideal repository for this information as it contains the requirements for installing EV charging stations in Article 625. Graphics and color-coding of load management equipment also could be included in NEC® Article 625.

Gap: **Labeling of EVSE and load management disconnects.** No standards currently exist for labeling EVSE and load management equipment.

Recommendation: EVSE manufacturers should develop standardized graphical symbols, disconnect instructions, and warning labels on their equipment. Requirements for graphics and color-coding of load management equipment connections and disconnects also could be included in NEC® Article 625. ***Priority:*** Near-term. ***Potential Developer:*** NFPA, SAE, ISO, IEC.

4.3.1.3 OEM Emergency Response Guides

ERGs written by the OEMs are more abridged than shop and owner's manuals and can be a valuable resource to emergency responders, though the amount of information is still lengthy and in non-standard formats across OEMs. NFPA is compiling the most crucial OEM information in their EV/Hybrid ERGs into a single database available in both standardized electronic and print formats for use by emergency responders and others as a quick reference on-scene guide. Manufacturers' labels and symbols are replicated, but once these are also standardized the ERG database will utilize the universal symbols.

No gaps have been identified at this time with respect to this issue.

4.3.1.4 Safe Battery Discharge / Recharge in Emergencies

Directions and procedures for the safe discharging / recharging of EV batteries following an incident may be unique depending upon the type of EV involved, the electrical control circuits in the vehicle, and the size and nature of its battery. There is a need to identify benchmarks to evaluate if a battery can be discharged in the field and a support system to allow it to be done in a timely manner. An opportunity for standardization might also be the location of on-board fast recharging instructions and/or standardized performance requirements. Hazard lights/signals (such as LED lights) and interlocks might be used to prevent fast recharging attempts when the battery is not safe to recharge due to damage or deterioration.

Gap: **Safe battery discharge / recharge in emergencies.** There do not appear to be standards addressing the discharge / recharge of EV batteries in emergency situations.

Recommendation*:* Standards and/or guidelines for safe battery discharge / recharge in emergencies are needed to ensure that the emergency responder user's interface is consistent and effective. ***Priority:*** Near-term. ***Potential Developer:*** SAE, NHTSA.

4.3.1.5 Workforce Training

Emergency First Responder Training

NFPA's Electric Vehicle Safety Training Project, funded by the U.S. Department of Energy and NFPA, is a nationwide program to help firefighters, law enforcement officers, emergency medical services and other first responders prepare for the growing number of hybrid and electric vehicles in the United States. This program provides information and materials necessary to safely respond to emergency situations involving advanced hybrid and electric vehicles on the road today. The training is designed to: create awareness of unique emergency response needs for electric vehicles; drive awareness of the availability of training modules and reference materials; remove concerns about the inherent safety of electric vehicles and the ability to safely respond to emergency situations; and reassure the public that trained first responders know what to do in emergency situations.

Key topics of NFPA's training include:

- Overview of the EV electrical and safety systems;
- Identification of electric and hybrid vehicles;
- Immobilization process;
- Electrical disabling procedures;
- EV extrication awareness, including high-strength steel;
- Vehicle fire recommended practices;
- Emergency operations (battery fire, submersion); and,
- New challenges presented by vehicle charging stations and infrastructure.

NFPA's web portal, www.EVsafetytraining.org, serves as a central repository for all EV safety information for first responders. This website hosts training, videos, and simulations; includes an events calendar, blogging, and news; and has a separate area for each auto manufacturer's safety information.

NFPA's training is provided via the following platforms:

- <u>Train-the-Trainer Classroom course:</u> An 8-hour "Train the Trainer" Emergency Responder course that covers the breadth of the program, along with strategies and learning objectives needed to train a group of first responders. Currently being achieved through a partnership with the North American Fire Training Directors, upon completion, attendees are capable of delivering the program to their own agency/department.

- <u>EV Safety Training Classroom Course:</u> A 4 hour face-to-face instructor-led program for firefighters, and a 3 hour face-to-face instructor-led program for law enforcement and emergency medical services, that provides instruction on how to respond to EV incidents.

- <u>Online Self-Paced Study Course:</u> An online, self-paced web version, complete with video, animations, simulations, data review exercises, and a final scenario room activity. A certificate is mailed to the user following successful completion of the course.

- <u>Vehicle Specific Online Training:</u> Chevrolet Volt Electric Vehicle safety training has been developed and released for the benefit of emergency responders on NFPA's EV web portal, with future model specific online training being released during the first quarter of 2012.

- <u>Emergency Field Guide:</u> This guide is a quick reference manual compiled from the manufacturers' emergency response guides, which contains the vital hybrid and electric vehicle safety information for a first responder on each make and model of hybrid or electric vehicle. This guide includes descriptions, diagrams, and locations of key high voltage EV components, as well as vehicle power down and emergency procedures in order to successfully identify, immobilize, and disable a hybrid or electric vehicle. This guide will be available in published and online formats.

Several first responder agencies have reported utilizing the training provided by vehicle manufacturers and other training consortiums. Law enforcement agencies have reported a need for increased access to first responder specific training. Law enforcement and emergency medical services need access to responder safety training designed for their respective roles but enabled to integrate with training of other responders to ensure efficient emergency operations.

Standards developing organizations can and should continue to foster such multi-discipline input into the development of standards and training programs regarding electric vehicles by including these perspectives on appropriate technical and standards development committees.

No gaps have been identified at this time with respect to this issue.

Harmonization Efforts

In contrast to the U.S., there is no centralized training portal for electric vehicle responder safety in Europe. Additionally, while the U.S. has developed a unified approach, where federal regulatory agencies, vehicle and charging station manufacturers, standards organizations and the first responder community have partnered to participate in the training and standards development process, no such partnership has evolved in the EU.

Second Responder/Normal Operations Training Programs

Organizations like the National Institute for Automotive Service Excellence (ASE), the American Automobile Association (AAA), and the Towing and Recovery Association of America Inc. (TRAA) have in place training programs and certifications for their technicians who perform service functions on electric vehicles. There does not appear to be a significant call for new training and/or certification programs at this time.

EVSE Installer and Inspector Training

EVSE installations must comply with local, state, and national codes and regulations. The installation process typically requires obtaining an electrical installation permit from local authorities, the use of a licensed contractor for the actual installation, and a final electrical review by a certified electrical inspector.

Article 625 of the National Electrical Code® (NEC®) sets forth installation safety requirements for typical hard-wired connections of EVSE, addressing wiring methods, equipment construction, control and protection, and equipment locations.

In order to support the build out of charging infrastructure for EVs nationally, a steadily expanding pool of qualified electrical installers and inspectors for EVSE is required.

The National Electrical Contractors Association (NECA) Workshop on Managing Electric Vehicle Supply Equipment (EVSE) – Electrical Contractors is a course that reviews necessary steps that must be performed to ensure system capacity of electrical power sources and service equipment and safe installation of EVSE branch circuits and feeders. It includes a review of applicable rules in the NEC® that must be applied to EVSE installations, including what constitutes qualifications of contractors and installers to perform EVSE installation. In addition to the minimum safety installation requirements of the NEC®, safe work practices and applicable workplace safety requirements are reviewed. Applicable performance and quality installation standards are integrated into this training program. Compliance with regulatory agencies is also reviewed specifically as it relates to required work permits, inspections, and approval of EVSE or vehicle charging equipment installations. The International Association of Electrical Inspectors (IAEI) has partnered with NECA to develop the EV training that NECA has been offering its chapters. This information is available to IAEI to develop training for inspectors and installers, but to date has not been fully developed. Upon completion, it is expected to provide 1-2 hours of training but be more NEC® Article 625 oriented, somewhat akin to an electrical check list.

The Electric Vehicle Infrastructure Training Program (EVITP) - Electrical Workers is a 14-18 hour class which comprehensively addresses the requirements, regulations, products and strategies which will enable electrical contractors and electricians to master successful, expert, and professional customer relations, installation, and maintenance of EV and PHEV infrastructure. Upon completion of this class, participants gain thorough knowledge and practical application of all covered EV infrastructure subjects including the critical areas of customer experience, protection of utility systems, and vehicle charging technical applications.

Additionally, Underwriters Laboratories, Inc. has developed a short (2.5 hr) e-learning course on Electric Vehicle Charging Station Installation for qualified electricians.

No gaps have been identified at this time with respect to this issue.

College and University Programs

As electric vehicle use increases, institutions of higher learning are beginning to address occupational needs with education and training programs. Many of these programs are taking advantage of DOE funding designed to increase adoption of electric vehicle technology. Programs vary from skill level training for those repairing and maintaining electric vehicles and charging equipment, to engineering programs for the next generation of designers.

The following educational institutions are known to offer electric vehicle training programs.

- J. Sargeant Reynolds Community College: The J. Sargeant Reynolds Community College in Virginia is currently developing a career studies certificate in advanced automotive technologies for electric vehicles. The courses include instruction on electric vehicles, plug-in hybrid electric vehicles, fuel cell electric vehicles, and control electronics.

- Purdue University: Purdue University is currently working with a group of other universities to develop over 30 courses supporting electric vehicle technology and workforce needs. These courses support two and four year students and certificate and workforce development programs.

- University of Central Missouri: The automotive technology management program at the University of Central Missouri proposes to develop a new certificate program for non-degree seeking individuals interested in advanced vehicle systems including electric vehicles, plug-in hybrid electric vehicles, fuel cell electric vehicles, and other future technologies. The possibility of developing this program into a minor is also being examined by the university. In addition, materials from this program can be condensed and adapted for outreach to community colleges and OEM partners. The certificate program will consist of six courses with all but the basic electronics course being taught by faculty holding the Automotive Service Excellence (ASE) master certification.

- University of Michigan, Ann Arbor: The University of Michigan offers undergraduate and graduate courses and degree programs related to electrified vehicles, with all of them targeting regular B.S., M.S and M.Eng. degrees (i.e., engineering students or professional engineers).

No gaps have been identified at this time with respect to this issue.

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5. Summary of Gaps and Recommendations

Priority: Near-term (0-2 yrs); Mid-term (2-5 yrs); Long-term (5+ yrs)

	Roadmap Issue	Section / page	Gap	Recommendation	Priority	Potential Developer	Grid Related
1.	Terminology	4.1 / 55	**Terminology.** There is a need for consistency with respect to electric vehicle terminology	Complete work to revise SAE J1715	Mid-term	ISO, SAE	No
2.	Power Rating Methods	4.1.1.1 / 56	**Power rating methods.** Standards for electric vehicle power rating methods are still in development	Complete work to develop SAE J2907 and J2908.	Mid-term	SAE	No
3.	Delayed Battery Overheating Events	4.1.1.2 / 58	**Delayed battery overheating events.** The issue of delayed battery overheating needs to be addressed.	Address the issue of delayed battery overheating events in future revisions of SAE J2929.	Near-term	SAE	No
4.	Loss of Control/Dual Mode Failure in the Battery	4.1.1.2/ 59	**Loss of control/dual mode failure in the battery.** The issue of double fault conditions in the battery needs to be addressed.	Future revisions of SAE J2929 should address loss of control/dual mode failure events such as a failure of overcharge protection when the battery is overheated, overheating during a crash event, or a cell thermal runaway event within the battery.	Mid-term	SAE	No
5.	Battery Testing - Performance and Durability	4.1.1.3 / 59	**Battery performance parameters and durability testing.** There is a need for further work on EV battery performance parameters and environmental durability test requirements.	Complete work on SAE J1798 and if possible consider harmonization with ISO 12405-2	Mid-term	SAE, ISO	No
6.	Battery Storage	4.1.1.4 / 60	**Safe storage of lithium-ion batteries.** At present, there are no standards addressing the safe storage of lithium-ion batteries specifically, whether at warehouses, repair garages, recovered vehicle storage lots, auto salvage yards, or battery exchange locations.	A standard on safe storage practices for EV batteries must be developed, addressing both new and waste batteries and the wide range of storage situations that may exist, including when the batteries are separated from their host vehicle.	Near-term	SAE, NFPA, ICC, IEC/TC 69	No
7.	Battery Packaging, Transport and Handling	4.1.1.4 / 61	**Packaging and transport of waste batteries.** Current standards and regulations do not adequately cover transportation aspects of *waste* batteries (damaged, aged, sent for repair, end-of-life) in terms of packaging, loading limitations, combination with other dangerous goods on same transport, etc.	There is a need for a harmonized approach toward communication, labeling, packaging restrictions, and criteria for determining when a battery is waste.	Near-term	ISO/TC 22/SC21, SAE or UL	No

	Roadmap Issue	Section / page	Gap	Recommendation	Priority	Potential Developer	Grid Related
8.	Battery Packaging, Transport and Handling	4.1.1.4 / 61	**Packaging and transport of batteries to workshops or battery swapping stations.** Unloading a battery in a battery swapping station is extremely challenging with the original packaging used for dangerous goods transportation. There is a need for standards for intermediate packaging to cover transport to battery swapping stations.	Intermediate packaging is required between the import location of the battery and battery swapping stations and needs to be standardized around geometry, safety and matching to UN packaging requirements.	Mid-term	ISO/TC 22/SC21, SAE or UL.	No
9.	Battery Recycling	4.1.1.5 / 62	**Battery recycling.** Standards are needed in relation to EV (li-ion) battery recycling.	EV (li-ion) battery recycling standards are desirable to address the calculation method toward recycling efficiency and recovery rates based on an agreed unit (possibly weight) and/or life-cycle assessment tools, including energy recovery.	Long-term	SAE, IEC	No
10.	Battery Secondary Uses	4.1.1.6 / 62	**Battery secondary uses.** There is a need for standards to address battery second life applications for grid storage and other uses.	Explore the development of standards for battery secondary uses, addressing such issues as safety and performance testing for intended applications, grid connection/communication interfaces, identification of parts/components that can be removed from the pack without destroying it, etc.	Long-term	SAE	Yes
11.	Crash Tests/ Safety	4.1.1.7 / 63	No Gap	N/A	N/A	N/A	No
12.	Internal High Voltage Cables, On-Board Wiring, Component Ratings and Charging Accessories	4.1.2.1 / 63	No Gap	N/A	N/A	N/A	No
13.	Vehicle Diagnostics - Emissions	4.1.2.2 / 66	No Gap	N/A	N/A	N/A	No
14.	Audible Warning Systems	4.1.2.3 / 67	**Audible warning systems.** Creation of the NHTSA safety standard and compliance with it will effectively close any gap with respect to audible warning systems for electric vehicles sold in the U.S. market. Ongoing standards work in SAE and ISO, and in WP.29 with respect to the development of a Global Technical Regulation (GTR) would provide a means for international harmonization around this issue.	Continue work on safety standards to address EV sound emission and measurement.	Near-term	SAE, ISO, NHTSA, WP.29	No

	Roadmap Issue	Section / page	Gap	Recommendation	Priority	Potential Developer	Grid Related
15.	Graphical Symbols	4.1.3.1 / 68	**Graphical symbols for electric vehicles.** Standards for graphical symbols for electric vehicles are needed to identify important terminals and parts visible under the hood, as well as to communicate information to the driver which can be understood regardless of the driver's language.	Complete work to develop SAE J2936. Develop EV graphical symbols standards for parts under the hood and to communicate information to the driver	Near-term	SAE, ISO, IEC	No
16.	Telematics – Driver Distraction	4.1.3.2 / 69	No Gap	N/A	N/A	N/A	No
17.	Fuel Efficiency, Emissions, and Labeling	4.1.3.3 / 70	No Gap	N/A	N/A	N/A	No
18.	Wireless Charging	4.2.1.1 / 71	**Wireless charging.** SAE J2954 on wireless charging design and UL 2750 on wireless charging safety are still in development.	Complete work on SAE J2954 and UL 2750.	Near-term	SAE, UL	Yes
19.	Battery Swapping	4.2.1.2 / 71	**Battery swapping – safety.** Currently, there is a need to define minimum requirements for the safe operation of battery swapping stations, as mass deployment of battery swapping systems is currently underway in several countries around the world.	Define minimum requirements for the safe operation of battery swapping stations.	Near-term	IEC/TC 69	No
20.	Battery Swapping	4.2.1.2 / 71	**Battery swapping – interoperability.** Standards are needed to help facilitate the penetration of battery swapping in the market. Issues to be addressed related to removable batteries include electrical interfaces, cooling integration, data transfer integration, and common mechanical and dimensional interfaces.	Define interoperability standards related to battery swapping.	Near-term	IEC/TC 69	No
21.	Power Quality	4.2.1.3 / 72	**Power quality.** SAE J2894/1 was published in December 2011. SAE J2894, Part 2, is still in development	Complete work on SAE J2894, Part 2.	Near-term	SAE	Yes
22.	EVSE Charging Levels/Modes	4.2.1.3 / 73	**EVSE charging levels.** The levels for DC charging within SAE J1772™ have yet to be finalized.	Complete work to establish DC charging levels within SAE J1772™.	Near-term	SAE	Yes
23.	Off-Board Chargers and Supply Equipment	4.2.1.3 / 75	**Off-board charging station and portable EV cord set safety within North America.** Harmonization of equipment safety standards within North America is underway based on the UL 2594 standard.	Finish efforts to harmonize standards addressing off-board charging station and portable EV cord set safety within North America.	Near-term	UL, CSA, ANCE (Mexico), NEMA	Yes

	Roadmap Issue	Section / page	Gap	Recommendation	Priority	Potential Developer	Grid Related
24.	Off-Board Chargers and Supply Equipment	4.2.1.3 / 75	**Off-board charger safety within North America.** Harmonization of equipment safety standards within North America is needed.	There appears to be a need to harmonize the safety requirements for off-board chargers with the U.S., Canada, and Mexico.	Mid-term	UL, CSA, ANCE (Mexico), NEMA	Yes
25.	Off-Board Chargers and Supply Equipment	4.2.1.3 / 75	**Off-board charger, off-board charging station and portable EV cord set safety globally.** There are some differences between the IEC 61851 series of standards and the North American standards. While not a gap per se with respect to the U.S. market, the use of infrastructure equipment and the means to mitigate risks would prove beneficial to manufacturers if harmonization was completed.	Work to harmonize the IEC 61851 series standards and the North American standards	Mid-term	UL, IEC	Yes
26.	EV Couplers: Safety and Harmonization Efforts	4.2.1.3 / 77	**EV coupler safety within North America.** Harmonization of EV coupler safety standards within North America is underway based on the UL 2251 standard.	Finish efforts to harmonize standards addressing EV coupler safety within North America.	Near-term	UL, CSA, ANCE (Mexico), NEMA	Yes
27.	EV Couplers: Safety and Harmonization Efforts	4.2.1.3 / 77	**EV coupler safety globally.** There are some differences between IEC 62196 series standards and the North American EV coupler safety standards. While not a gap per se with respect to the U.S. market, global harmonization would help to reduce costs for vehicle manufacturers.	Work to harmonize the IEC 62196 series standards and the North American EV coupler safety standards.	Mid-term	UL, IEC	Yes
28.	EV Couplers: Interoperability and Harmonization Efforts	4.2.1.3 / 79	**EV coupler interoperability globally.** Different coupler configurations are used in different parts of the world. While not a gap per se with respect to the U.S. market, global harmonization would help to reduce costs for vehicle manufacturers.	Work to harmonize EV coupler configurations in particular with respect to DC charging.	Near-term	SAE, IEC, CHAdeMO	Yes
29.	EV Couplers: Interoperability – Conformance Programs	4.2.1.3 / 79	**Conformance programs for EV coupler interoperability within the U.S. market.** No programs yet exist for the U.S. market to verify compatibility between the EV coupler, the infrastructure and the vehicle.	Complete work on SAE J2953. Establish a program(s) to verify interoperability between infrastructure equipment, including the vehicle connector, and all vehicles that follow the SAE J1772™ protocol.	Near-term	SAE, UL	Yes
30.	EMC	4.2.1.4 / 80	No Gap	N/A	N/A	N/A	Yes

	Roadmap Issue	Section / page	Gap	Recommendation	Priority	Potential Developer	Grid Related
31.	Vehicle as Supply	4.2.1.5 / 81	**Vehicle as supply / reverse power flow.** Standards to address communications and safety aspects of reverse power flow in V2G, V2H, V2L and V2V applications are still in development.	Complete work to address communications and safety aspects of reverse power flow in SAE J2836/3™ and SAE J2836/5™, and SAE J2847/3 and SAE J2847/5. Address reverse power flow safety aspects in IEEE standards.	Near-term	SAE, IEEE	Yes
32.	Use of Alternative Power Sources	4.2.1.6 / 82	**Use of alternative power sources.** The National Electrical Code® does not specifically address the integration of the EV and EVSE with a facility high voltage DC power distribution system for either charging or reverse power flow.	Develop NEC® requirements for high voltage DC power distribution systems and the integration of distributed energy resources and DC loads with the system	Near-term	NFPA	Yes
33.	Reserving Charging Stations (EVSE)	4.2.2 / 86	**Locating and reserving a public charging station**. There is a need for a messaging standard to permit EV drivers to locate a public charging spot and reserve its use in advance.	Develop a messaging standard to permit EV drivers to universally locate and reserve a public charging spot.	Mid-term	SAE, ISO/IEC JWG, NEMA	Yes
34.	Roaming	4.2.2 / 86	**Charging of roaming EVs between EVSPs**. There is a need to permit roaming EVs to charge at spots affiliated with a different EVSP.	Develop back end requirements as well as an interface standard that supports charging of roaming EVs between EVSPs.	Near-term	NEMA, IEC	Yes
35.	Access Control	4.2.2 / 87	**Access control at charging stations**. There is a need to develop data definition and messaging standards for communicating access control at charging stations.	Develop data definition and messaging standards for communicating access control at charging stations	Near-term	NEMA	Yes
36.	Telematics – Communications Interoperability	4.2.2 / 87	No Gap (requires further discussion)	N/A	N/A	N/A	Yes

	Roadmap Issue	Section / page	Gap	Recommendation	Priority	Potential Developer	Grid Related
37.	Communication of Standardized EV Sub-metering Data	4.2.2 / 88	**Communication of standardized EV sub-metering data**. Standards for communication of standardized EV sub-metering data are needed.	Continue work to develop standards for communication of standardized EV sub-metering data.	Near-term	ZigBee Alliance, NAESB	Yes
38.	Site Assessment / Power Capacity Assessment	4.2.3.1 / 89	No Gap	N/A	N/A	N/A	Yes
39.	EV Charging and Parking - Urban Planning	4.2.3.2 / 91	No Gap	N/A	N/A	N/A	Yes
40.	Charging Station Permitting	4.2.3.3 / 91	No Gap	N/A	N/A	N/A	Yes
41.	Environmental and Use Conditions	4.2.3.4 / 93	No Gap	N/A	N/A	N/A	No
42.	Ventilation - Multiple Charging Vehicles	4.2.3.5 / 94	No Gap	N/A	N/A	N/A	No
43.	Guarding of EVSE	4.2.3.6 / 95	**Guarding of EVSE.** There is a lack of standards that address charging station design with respect to physical and security protection of the equipment.	Guidelines or standards relating to guarding of EVSE should be developed.	Mid-term	NHTSA or AASHTO	No
44.	Accessibility for Persons with Disabilities to EVSE	4.2.3.7/ 95	**Accessibility for Persons with Disabilities to EVSE.** There is a lack of standards that address charging station design with respect to accessibility for persons with disabilities to EVSE.	Guidelines or standards relating to accessibility for persons with disabilities to EVSE should be developed.	Mid-term	ICC (ASC A117 and IBC®).	No
45.	Cable Management	4.2.3.8 / 96	**Cable management.** There is a lack of standards or code provisions that address functional management of EV cables in public parking spaces.	Guidelines or standards relating to EVSE cable management should be developed.	Mid-term	UL, NFPA	No
46.	EVSE Maintenance	4.2.3.9 / 96	No Gap	N/A	N/A	N/A	No
47.	Workplace Safety Installation	4.2.3.10 / 97	No Gap	N/A	N/A	N/A	No

	Roadmap Issue	Section / page	Gap	Recommendation	Priority	Potential Developer	Grid Related
48.	Vehicle Emergency Shutoff, Including Labeling of High Voltage Batteries, Power Cables, and Disconnect Devices	4.3.1.1 / 97	**Vehicle emergency shutoff, including labeling of high voltage batteries, power cables, and disconnect devices.** Standards are needed in terms of safety labeling of high voltage batteries, power cables, and disconnect devices.	Develop standards for safety labels for electric vehicle batteries, power cables, and disconnect devices to enable emergency responders and service personnel to quickly and easily recognize them and to avoid electrical shock hazards.	Near-term	NFPA, SAE, ISO, IEC	No
49.	Labeling of EVSE and Load Management Disconnects	4.3.1.2 / 98	**Labeling of EVSE and load management disconnects.** No standards currently exist for labeling EVSE and load management equipment.	EVSE manufacturers should develop standardized graphical symbols, disconnect instructions, and warning labels on their equipment. Requirements for graphics and color-coding of load management equipment connections and disconnects also could be included in NEC® Article 625.	Near-term	NFPA, SAE, ISO, IEC	No
50.	OEM Emergency Response Guides	4.3.1.3 / 99	No Gap	N/A	N/A	N/A	No
51.	Safe Battery Discharge / Recharge in Emergencies	4.3.1.4 / 99	**Safe battery discharge / recharge in emergencies.** There do not appear to be standards addressing the discharge / recharge of EV batteries in emergency situations.	Standards and/or guidelines for safe battery discharge / recharge in emergencies are needed to ensure that the emergency responder user's interface is consistent and effective.	Near-term	SAE, NHTSA	No
52.	Workforce Training	4.3.1.5 / 99	No Gap	N/A	N/A	N/A	No

6. Next Steps – A Living Document

It is envisioned that this roadmap will be widely promoted and that its recommendations will see broad adoption. At the same time, the ecosystem for EVs and charging infrastructure is rapidly evolving and adapting due to technological changes with resulting policy implications. In order for this roadmap to be widely useful and relevant to broad stakeholder communities over an extended period of time, it is essential that it adapts in parallel.

In response, the roadmap has been structured to maximize clarity, to highlight the evolving interfaces and interrelationships between standards and conformance activities within various domains and topical areas, and to promote flexibility while emphasizing simplification, consolidation, and streamlining in response to gaps in the EV standards landscape. It is structured to be convenient to navigate, with clear delineations and with specific types of information found only within one location of the document, to ease future modifications.

While this version of the roadmap represents a specific snapshot in time, it maintains a distinctively outward looking, over the horizon posture that will facilitate discussions with domestic, regional and international partners regarding coordination and harmonization of standardization activities and adaptation to technological and policy changes.

Moving forward, new elements of the roadmap will build on the foundation created here in anticipation of potential game changers resulting from revolutionary technology introductions and policy changes, or unforeseen incidents that could significantly impact the standards landscape for EVs and charging infrastructure.

Depending upon the realities of the standards environment, needs of stakeholders, and available resources, this roadmap will be periodically updated. It is envisioned that a first update will occur twelve to fifteen months after publication of this version one. During that time, it is anticipated that the ANSI EVSP will continue to assess the progress of standards and conformance programs, as well as gaps, focusing on developing issues that are new or that require further discussion, e.g., where consensus may not have been achievable for this version. A draft version two can be maintained as a repository for such new developments and updates.

As part of this process, the interfaces and coordination of standards and conformance activities across domains and topical areas will be cross walked and reevaluated. Ultimately, the aim is to provide a living roadmap that will serve to help guide, coordinate, and enhance the standards landscape in support of the widespread introduction of PEVs and charging infrastructure.

Appendix A. EV Charging Actors and Communications

Introduction

This appendix defines the various EV charging actors or communicating entities, and describes the communication between various pairs of actors, with examples.

Actors

EV

Electric Vehicle

EV Authorizer

A driver of an EV, or entity that requests charging of an EV

EVSE

Electric Vehicle Supply Equipment – the device that safely conveys electricity to the on-board charger of the EV. For the purposes of this document, EVSE is synonymous with "charging station." An EVSE may be "dumb," i.e., incapable of communication, or "intelligent," i.e., capable of communication and able to control aspects of charging based on the communication.

Off-board charger

A charging module that resides outside the EV and delivers DC current to the EV (e.g., for DC Charging)

EMS

Energy Management System – A logical entity that manages energy consumption in a home/building/premises. This may be controlled by a consumer (e.g., homeowner, premises owner) or an Energy Service Provider (e.g., a utility).

EV Services Provider (EVSE Host Management Services)

An entity that provides services related to EV charging, such as locating charging stations, reserving charging stations, subscription/fee-based charging, status/alerts via smart phones, etc. This entity may be an Energy Service Provider, such as a utility, or an independent company providing these services, a municipality, etc.

Fleet Operator

An operator of a set of EVs for private or public use, such as a corporation, an auto rental company, a taxi service, or a municipality

NAV/GPS

A device or service, such as a portable GPS system, that enables geo-location of charging stations

Energy Retailer

A seller of electricity and related services such as customer service and billing. An energy retailer uses the generation, transmission and distribution services provided by a utility (or by a power generation company and a Transmission and Distribution Services Provider).

Financial Clearing House

A third-party entity that provides services enabling clearing and settlement of a transaction between two parties. For example, a clearing house may be required to settle a transaction between two providers, when the customer of one provider "roams" and charges at the second provider's charging station.

Financial Processor

On-site, premises-based infrastructure that requests financial transaction authorization

Auxiliary Services Provider

Auxiliary Services is an umbrella term denoting any non-charging related services that can be provided to an EV or EV user via the smart grid. For example, OEMs (automobile manufacturers) may be able to transmit information to the EV while it is charging.

Energy Service Provider

An entity that generates, transmits, and distributes electrical power (e.g., a utility)

Types of Communication, Broken Down by the Peers Involved

EV – EV Authorizer

Communication between an EV and its user or authorizer. Although the user interface and possibly much of the communication involved may be proprietary, it may be useful to standardize a basic level of communication that covers alerts and status.

EV – EVSE

Communication between an EV and the EVSE to which it is physically connected. This communication is used for authentication, authorization of charging, metering and sign-off by the EV of metering data; communicating EV data such as state of charge (SOC) to the EVSE/EMS/grid; selection of charging plan and time based on available tariff information obtained from the EVSE, etc. Depending on whether the EV, the EVSE or both are intelligent, the communication to the grid may be performed by either (or both) of them.

EV – Off-board charger (DC)

Communication between an off-board charger and the EV

EV – Home/Building/Premises EMS

An EMS may control multiple devices that act as loads or sources in the home/building/premises. Communication between the EV and the EMS provides the EMS with information about the EV charging requirements, real-time status, errors etc. The EMS may control charging parameters such as start/stop time and amount of energy dispensed. It may also act as a proxy for the energy retailer/provider, by acting on demand response messages, adapting charging schedules based on the grid status, and managing reverse energy flow to the grid (V2G).

EV – EV Services Provider

An EV may communicate with an EV Services Provider (in cases where the EVSE acts as a PLC-Zigbee bridge), and exchange messages related to state of charge (SOC), selection of charging parameters based on tariffs, demand response, etc.

EV – Fleet Operator

TBD (to be determined)

EV – NAV/GPS

TBD

EV – Energy Retailer

The EV and the Energy Retailer may communicate directly with each other (in certain scenarios such as when an EVSE acts as a PLC-ZigBee bridge) and exchange messages related to pricing/tariffs, demand response, metering, etc.

EV – Auxiliary Services Provider

An Auxiliary Services Provider (such as an EV manufacturer) may communicate with the EV in order to update software, get status, etc.

EV – Energy Service Provider

The EV and the Energy Service Provider may communicate directly with each other (in certain scenarios such as when an EVSE acts as a PLC-ZigBee bridge) and exchange messages related to pricing/tariffs, demand response, metering, etc.

EV Authorizer – EVSE

The interaction between an EV Authorizer and an EVSE will probably take place via a user interface or via an EMS or EV Services Provider, rather than via direct communications.

EVSE – EV Services Provider

EVSEs are managed by an EV Services Provider. The communication involved relates to status, diagnostics, reservations, pricing, access control, metering data, demand response, etc.

EVSE – Fleet Operator

TBD

EVSE – EMS (Home/Building/Premises Automation)

The EVSE may be managed by the EMS that controls charging parameters, demand response, etc.

EVSE – Energy Retailer

The EVSE and the Energy Service Provider may communicate directly with each other and exchange messages related to pricing/tariffs, demand response, metering, etc.

EVSE – Energy Service Provider

The EVSE and the Energy Service Provider may communicate directly with each other and exchange messages related to pricing/tariffs, demand response, metering, etc.

EV Services Provider - EV Services Provider

Two EV Services Providers may communicate directly or via a third-party when the customer of one provider charges at a station managed by the other. This communication would include authentication, authorization, accounting, and settlement.

EV Services Provider – Fleet Operator

Fleets can communicate with EV Services Providers to monitor the charging status of the fleet vehicles, track charging history, remotely update smart EVSEs, etc.

EV Services Provider – Home/Building/Premises EMS

An EMS or Building/Premises automation system may query charging records from the EV Services Provider that manages the charging stations at the building/premises. Also, charging constraints such as time of charge, energy to be dispensed, and access control may need to be communicated to EVSEs via the EV Services Provider.

EV Services Provider – NAV/GPS

A NAV/GPS application or device may require both static and dynamic data about charging stations managed by an EV Services Provider. Static data such as location and type may be provided via a global database, but dynamic information such as availability and pricing needs messaging.

EV Services Provider – Energy Retailer

Communication between an EV Services Provider and an Energy Retailer may include demand response and pricing related messaging, as well as charging records.

EV Services Provider – Financial Clearing House

An EV Services Provider may need to use a Financial Clearing House for settlement of transactions between an EV/authorizer and itself, or another charging service provider and itself.

EV Services Provider – Energy Service Provider

Communication between an EV Services Provider and an Energy Service Provider may include demand response and pricing related messaging, as well as charging records.

Fleet Operator – Energy Retailer

TBD. This communication may be substantially similar to EMS – Energy Service Provider communication.

Fleet Operator – Financial Clearing House

TBD

Fleet Operator – Energy Service Provider

TBD. This communication may be substantially similar to EMS – Energy Service Provider communication.

EMS – Energy Retailer

Communication between the EMS and an Energy Retailer may include handling of demand response, DER (Distributed Energy Resources, e.g., for energy flow from the EV to the grid), pricing/tariff related information, etc.

EMS –Energy Service Provider

Communication between the EMS and an Energy Service Provider may include handling of demand response, DER (Distributed Energy Resources, e.g., for energy flow from the EV to the grid), pricing/tariff related information, etc.

Financial Clearing House – EV Services Provider

A financial clearing house may be required in order to settle roaming charges between a home Services provider, and a visited Services provider.

Financial Clearing House – Energy Retailer

TBD

Financial Clearing House (FCH) – Energy Service Provider

TBD

Appendix B. Glossary of Acronyms and Abbreviations

See also *Appendix !‹ EV Charging Actors and Communications* and the *ANSI EVSP Roadmap Standards Compendium*.

AC – Alternating Current

ANCE (Mexico) - La Asociación Nacional de Normalización y Certificación del Sector Eléctrico, A.C.

BEV – Battery Electric Vehicle

CEN – European Committee for Standardization

CENELEC – European Committee for Electrotechnical Standardization

DC – Direct Current

DOE – U.S. Department of Energy

EPRI – Electric Power Research Institute

EREV – Extended Range Electric Vehicle

EV – Electric Vehicle

EVSE – Electric Vehicle Supply Equipment

FMVSS – Federal Motor Vehicle Safety Standards

GTR – Global Technical Regulation

HAN – Home Area Network

HEV – Hybrid Electric Vehicle

IBC® – International Building Code®

ICC – International Code Council

IEC – International Electrotechnical Commission

IFC® – International Fire Code®

IgCC™ – International Green Construction Code™

IMC® – International Mechanical Code®

IEEE – Institute of Electrical and Electronics Engineers

IRC® – International Residential Code® for One- and Two-Family Dwellings

ISO – International Organization for Standardization

NAN – Neighborhood Area Network

NEC® – NFPA 70®, the National Electrical Code®

NECA – National Electrical Contractors Association

NEMA – National Electrical Manufacturers Association

NFPA – National Fire Protection Association

NHTSA – National Highway Traffic Safety Administration

OEM – Original Equipment Manufacturer

PEV – Plug-in Electric Vehicle

PHEV – Plug-in Hybrid Electric Vehicle

PLC – Power Line Communication

RPF – Reverse Power Flow

SAE – SAE International

SDO – Standards Development Organization

UL – Underwriters Laboratories, Inc.

UNECE – United Nations Economic Commission for Europe

V2G – Vehicle to Grid

V2H – Vehicle to Home

V2L – Vehicle to Load

V2V – Vehicle to Vehicle

WP.29 – World Forum for Harmonization of Vehicle Regulations

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